The Cornerstone 22 inch, flat face monitor (selling price $780) is new both in its flat face CRT and in its electronics. NIDL has verified that this monitor achieves stereo mode operation at 1024 x 1024 addressability at 120 Hz and also at 1280 x 1024 at 118 Hz. NIDL rates this color monitor “B” in monoscopic mode and “C” in stereoscopic mode and thereby certifies the 22 inch Cornerstone p1750 color monitor as being suitable for IEC workstations for monoscopic mode only. Compared to the P1700, the p1750 has lower luminance in both the monoscopic and stereoscopic modes, more halation, and lower refresh rate capability in stereo. Briggs Scores in monoscopic mode for the BTP #4 Delta-1, Delta-3, Delta-7 and Delta-15 contrast ratio targets sets averaged 8, 46, 57 and 61, respectively, for the p1750 monitor in 1600 x 1200 monoscopic mode. These scores were comparable to the P1700 monitor and slightly lower than the scores for the Sony GDM-F520 monitor.

Evaluation of the Cornerstone p1750 22-Inch Diagonal Color CRT Monitor for Monoscopic and Stereoscopic Imagery

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Publication No. 750811201-130

December 20, 2001

Report Documentation Page

Report Date	Report Type	Dates Covered (from... to)
20122001	N/A	-

Title and Subtitle Evaluation of the Cornerstone p1750 22-Inch Diagonal Color CRT Monitor for Monoscopic and Stereoscopic Imagery	**Contract Number**
	Grant Number
	Program Element Number
Author(s)	**Project Number**
	Task Number
	Work Unit Number
Performing Organization Name(s) and Address(es) National Information Display Laboratory P. O. Box 8619 Princeton, NJ 08543-8619	**Performing Organization Report Number**
Sponsoring/Monitoring Agency Name(s) and Address(es)	**Sponsor/Monitor's Acronym(s)**
	Sponsor/Monitor's Report Number(s)
Distribution/Availability Statement Approved for public release, distribution unlimited	
Supplementary Notes The original document contains color images.	
Abstract	
Subject Terms	
Report Classification unclassified	**Classification of this page** unclassified
Classification of Abstract unclassified	**Limitation of Abstract** UU
Number of Pages 53	

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NIDL IEC Monitor Certification Report

The Cornerstone p1750 Color CRT Monitor

FINAL GRADES
Monoscopic Mode: B
Stereoscopic Mode: C

A=Substantially exceeds IEC Requirements; B= Meets IEC Requirements; C=Nearly meets IEC Requirements; F=Fails to meet IEC Requirements in a substantial way.

Color monitors are more difficult to evaluate and their performance may not compare to monochrome monitors. Color monitors have three electron guns (R, G, and B) to focus and converge. They also have a perforated steel shadow mask that separates the colors on the screen and this adds complexity. Color lines formed on the phosphor screen may not be as narrow as for a monochrome, single electron gun-formed spot. The color monitor's light output may not be as high. The IEC monitor specifications for color monitors reflect this difference, and have lower luminance and stereo extinction ratio requirements than a monochrome monitor. In spite of these limitations, Imagery and Geospatial Analysts at a number of sites may do all their analyses on color monitors.

The Cornerstone p1750 22-inch monitor (selling price $780) is new in its flat face Trinitron-type CRT manufactured by Mitsubishi. It has a phosphor pitch of 0.25 mm over the entire face and 2048 x 1536 pixel maximum addressability. The Cornerstone P1700 monitor has curved face with a phosphor dot screen.

NIDL has verified that this monitor achieves stereo mode operation at 1024 x 1024 addressability at 120 Hz. The Cornerstone p1750 is being offered by the manufacturer as a replacement for the previous model Cornerstone P1700 color monitor that NIDL had certified for IEC workstation monoscopic and stereoscopic mode color operation. NIDL rates the p1750 color monitor "B" in monoscopic mode and "C" in stereoscopic mode and thereby certifies the 22 inch Cornerstone p1750 color monitor as being suitable for IEC workstations for monoscopic mode only. Compared to the P1700, the p1750 has lower luminance in both the monoscopic and stereoscopic modes, more halation, and lower refresh rate capability in stereo. NIDL tested the monitor at an addressability of 1600 x 1200 pixels, as would be used in an IEC W2K PC–based workstation. Our tests show that the monoscopic contrast modulation is excellent and exceeds 60% in Zone A and 54% over the face of the whole CRT, well above the IEC minimum performance values.

Briggs scores for the BTP #4 Delta-1, Delta-3, Delta-7 and Delta-15 contrast ratio targets sets averaged 8, 40, 53 and 57, respectively, for the Cornerstone p1750 monitor. The p1750 scores were comparable to the Cornerstone P1700 monitor and were somewhat lower than the Sony GDM-520 monitor.

The p1750 Cornerstone monitor exhibits screen-loading effects on luminance. When the contrast control is set to maximum, the luminance of a white 2-inch square target increases by 30% compared to the luminance of full screen white.

The color temperature can be preset to 5000, 6500, and 9300K, or can be user-adjusted. The luminance of a white full screen, Lmax, is the same for both 9300K and 6500K preset color temperatures.

The manufacturer lists the maximum addressability for the Cornerstone p1750 as 2048 x 1536 pixels. However, the horizontal phosphor pitch of 0.25 mm limits the number of red, green and blue phosphor stripes that can be addressed to fewer than 2048 pixels in the horizontal direction. As evaluated, NIDL's measurements for a viewable image size of 15.234 x 11.463 inches indicate a maximum of 1548 pixels in the horizontal direction based on the horizontal phosphor pitch.

NIDL verified that the p1750 monitor is able to display 1024 x 1024 pixel stereo images at 60 Hz per eye (120 Hz vertical refresh rate and 129.417 kHz horizontal scan rate), which meets the IEC specification of 60 Hz per eye and exceeds the manufacturer specified maximum horizontal scan rate of 127 kHz. For comparison, the Cornerstone P1700 has a specified maximum horizontal scan rate of 130 kHz, somewhat higher than the p1750. With a value of 18:1 at 60 Hz per eye, the monitor exceeds the IEC stereo extinction ratio specification of 15:1 with the StereoGraphics CrystalEyes shutter glasses. With the StereoGraphics ZScreen and passive polarized glasses, Lmax is 5.1 fL at the analyst’s eye position, somewhat lower than the 6.78 fL measured for the P1700. Further, in stereo mode, NIDL could not achieve Lmin more than 0.051 fL through the ZScreen and passive glasses.

The Cornerstone p1750 is compared in Table II with other color monitors that NIDL has certified for monoscopic-mode only. Other color CRT monitors certified by NIDL for monoscopic and stereoscopic-mode operation are listed in Table I.

Table I. NIDL IEC Color Monitor Certified for Stereoscopic-Mode Application (Have Rating B or Higher for Both Monoscopic and Stereoscopic Modes)

Monitor	**IEC Spec**	**Sony**	**Cornerstone**	**EIZO**	**Hitachi**	**Siemens**	**Viewsonic**
Model		GDM-F520	P1700	F980	CM814	SCM21130	P817
Certified for stereoscopic*		Y	Y	Y	Y	Y	Y
Monoscopic		A	A	B	B	B	B
Stereoscopic		A	B	B	B	B	B
Cm, Zone A	25%	43%	57%	37%	35%	36%	29%
Cm, Zone B	20%	41%	52%	27%	30%	21%	40%
Refresh per eye	60 Hz	60.5 Hz	60 Hz	60 Hz	60 Hz	60.5 Hz	60 Hz
Extinction ratio, panel	No spec	12.5	10.6	12.6	11.2	11.2	10.1
IR glasses	15 to 1	25.7	21.0	14.3		18.1	
Price		$1700	$1363	$1790	$1200	< $2800	$1600

* Certified by NIDL requires achieving a rating of “B” or above for stereoscopic and for monoscopic performance relative to the IEC Working Group specifications listed in the Evaluation Datasheet. This summary is a compilation of ratings for color monitors from previously NIDL IEC monitor reports.

Table II. NIDL Certification for Imagery Exploitation Capability for Color Monitors Intended for Monoscopic-Only Applications Application (Have Rating B or Higher for Monoscopic Mode)

Monitor Manufacturer	**IEC Spec**	**Cornerstone 22 inch**	**Viewsonic 21 inch**	**Mitsubishi 22 inch**	**SONY 24 inch Tested at 1920 x 1200 addressability**	
Model		p1750	PF815	2040U	24W900	GDM-FW900
Certified for monoscopic-only*		Y	Y	Y	Y	Y
Monoscopic		B	A	A	A	A
Stereoscopic		C	C	C		C
Cm, Zone A	25%	60%	55%	54%	51%	48%
Cm, Zone B	20%	54%	47%	42%	35%	38%
Refresh per eye	60 Hz	60 Hz	55 Hz	55 Hz	46 Hz	56 Hz
Extinction ratio, panel	No spec	11.0	10.3	10.4	12.9	11.1
IR glasses	15 to 1	18.0	17.6	17.6		18.7
Price		$780	$926	$1123	$2371	$1999

Evaluation Datasheet for Cornerstone P1700 and p1750 Monitors

		Cornerstone P1700		Cornerstone p1750	
Mode	**IEC Requirement**	**Measurement**	**Compliance**	**Measurement**	**Compliance**
MONOSCOPIC					
Addressability	1024 x 1024 min.	1600 x 1200	Pass	1600 x 1200	Pass
Contrast Ratio (Dynamic Range)	300:1 (24.8 dB)	25.4 dB	Pass	304:1 (24.8 dB)	Pass
Luminance (Lmin)	0.1 fL ± 4% min.	0.1 fL	Pass	0.10 fL	Pass
Luminance (Lmax)	30 fL ± 4%	34.8 fL	Pass	30.4 fL	Pass
Uniformity (Lmax)	20% max.	11.5 %	Pass	10.7 %	Pass
Halation	3.5% max.	4.17 ± 0.4%	Fail	6.55% +/- 0.5%	Fail
Color Temp	6500 to 9300 K ± 0.01 Δu'v' max.	9075 K	Pass	9830 K	Pass
Reflectance	Not specified	5.0 %	Good	5.2%	Good
Bit Depth	8-bit± 5 counts	8-bit	Pass	8-bit	Pass
Step Response	No visible ringing	Clean	Pass	Clean	Pass
Uniformity (Chromaticity)	0.010 ± 0.005 Δu'v' max.	0.0022 Δu'v'	Pass	0.005 Δu'v'	Pass
Pixel aspect ratio	Square, H = V± 6%	H = V – 0.4%	Pass	H = V+ 0.3%	Pass
Screen size, viewable diagonal	17.5 to 24 inches ± 2 mm	19.7 ins.	Pass	19.065 inches	Pass
Raster Modulation Center, Lmax	Not specified			Cm = 2%	
Cm, Zone A, 7.6"	25% min.	57% H x 82% V	Pass	86% H x 62% V	Pass
Cm, Zone A, 9.4”	25% min.	56% H x 83% V	Pass	85% H x 60% V	Pass
Cm, Zone B	20% min.	52% H x 86% V	Pass	83% H x 54% V	Pass
Pixel density	72 ppi min.	101 ppi	Pass	105 ppi	Pass
Moiré, phosphor-to-pixel spacing	1.0 max	0.88	Pass	1.03	Fail
Straightness	0.5% ± 0.05 mm max.	< 0.26 %	Pass	< 0.21%	Pass
Linearity	1.0% ± 0.05 mm max	< 0.66 %	Pass	< 0.32%	Pass
Jitter	2 ± 2 mils max.	< 2.63 mils	Pass	< 3.85 mils	Pass
Swim, Drift	5 ± 2 mils max.	< 3.04 mils	Pass	< 4.34 mils	Pass
Warm-up time, Lmin to +/- 50%	30 ± 0.5 mins. max	25 mins.	Pass	10 minutes	Pass
Warm-up time, Lmin to +/- 10%	60 ± 0.5 mins. max	60.mins.	Pass	48 minutes	Pass
Refresh	72 ±1 Hz min. 60 ±1 Hz absolute min	Set to 85 Hz	Pass	Set to 75 Hz	Pass
Briggs BTP#4	Not specified	Δ1 = 9, Δ3 = 40 Δ7 = 53, Δ15 = 57		Δ1 = 8, Δ3 = 40 Δ7 = 53, Δ15 = 57	
STEREOSCOPIC					
Addressability	1024 x 1024 min.	1024 x 1024 (Z) (IR)	Pass	1024 x 1024	Pass
Lmin	Not specified	0.1 fL	Pass	0.051fL (Z), 0.059fL (IR)	Fail
Lmax	6 fL min ± 4%	6.78fL (Z)	Pass	5.1fL (Z), 6.0fL (IR)	Fail
Dynamic range	17.7 dB min	17.9dB (Z)	Pass	20.0dB (Z), 20.1dB (IR)	Pass
Uniformity (Chromaticity)	0.02 ± 0.005 Δu'v' max	0.010 Δu'v' (Z)	Pass	0.006 Δu'v'	Pass
Refresh rate	60 Hz per eye, min	60 Hz per eye (Z) (IR)	Pass	60.0 Hz per eye	Pass
Extinction Ratio	15:1 min	10.6:1 (Z) 21.0:1 at 60 Hz (IR)	Pass	11:1 (Z), 18:7 (IR)	Pass

(Z) Denotes StereoGraphics ZScreen and Eyewear (IR) Denotes StereoGraphics CrystalEyes IR Eyewear

Evaluation Datasheet for Sony GDM-F520 and p1750 Monitors

		Sony GDM-F520		Cornerstone p1750	
Mode	**IEC Requirement**	**Measurement**	**Compliance**	**Measurement**	**Compliance**
MONOSCOPIC					
Addressability	1024 x 1024 min.	1600 x 1200	Pass	1600 x 1200	Pass
Contrast Ratio (Dynamic Range)	300:1 (24.8 dB)	318:1 (25.0 dB)	Pass	304:1 (24.8 dB)	Pass
Luminance (Lmin)	0.1 fL ± 4% min.	0.10 fL	Pass	0.10 fL	Pass
Luminance (Lmax)	30 fL ± 4%	31.8 fL	Pass	30.4 fL	Pass
Uniformity (Lmax)	20% max.	6.0 %	Pass	10.7 %	Pass
Halation	3.5% max.	3.88% +/- 0.33%	Pass	6.55% +/- 0.5%	Fail
Color Temp	6500 to 9300 K ± 0.01 Δu'v' max.	6941 K	Pass	9830 K	Pass
Reflectance	Not specified	6.2%	Good	5.2%	Good
Bit Depth	8-bit± 5 counts	8-bit	Pass	8-bit	Pass
Step Response	No visible ringing	Clean	Pass	Clean	Pass
Uniformity (Chromaticity)	0.010 ± 0.005 Δu'v' max.	0.002 Δu'v'	Pass	0.005 Δu'v'	Pass
Pixel aspect ratio	Square, H = V± 6%	H = V+ 0.6%	Pass	H = V+ 0.3%	Pass
Screen size, viewable diagonal	17.5 to 24 inches ± 2 mm	19.074 inches	Pass	19.065 inches	Pass
Raster Modulation Center, Lmax	Not specified	Cm = 4%		Cm = 2%	
Center Screen, 50% Lmax	Not specified	Cm = 7%		Not measured	
Cm, Zone A, 7.6"	25% min.	70% H x 43% V	Pass	86% H x 62% V	Pass
Cm, Zone A, 9.4”	25% min.	71% H x 42% V	Pass	85% H x 60% V	Pass
Cm, Zone B	20% min.	71% H x 41% V	Pass	83% H x 54% V	Pass
Pixel density	72 ppi min.	105 ppi	Pass	105 ppi	Pass
Moiré, phosphor-to-pixel spacing	1.0 max	0.91	Pass	1.03	Fail
Straightness	0.5% ± 0.05 mm max.	< 0.15%	Pass	< 0.21%	Pass
Linearity	1.0% ± 0.05 mm max	< 0.81%	Pass	< 0.32%	Pass
Jitter	2 ± 2 mils max.	< 3.57 mils	Pass	< 3.85 mils	Pass
Swim, Drift	5 ± 2 mils max.	< 4.27 mils	Pass	< 4.34 mils	Pass
Warm-up time, Lmin to +/- 50%	30 ± 0.5 mins. max	24 minutes	Pass	10 minutes	Pass
Warm-up time, Lmin to +/- 10%	60 ± 0.5 mins. max	60 minutes	Pass	48 minutes	Pass
Refresh	72 ±1 Hz min. 60 ±1 Hz absolute min	Set to 85 Hz	Pass	Set to 75 Hz	Pass
Briggs BTP#4	Not specified	Δ1 = 8, Δ3 = 46 Δ7 = 57, Δ15 = 61		Δ1 = 8, Δ3 = 40 Δ7 = 53, Δ15 = 57	
STEREOSCOPIC					
Addressability	1024 x 1024 min.	1024 x 1024	Pass	1024 x 1024	Pass
Lmin	Not specified	0.1 fL	Pass	0.051fL$^{(Z)}$, 0.059fL $^{(IR)}$	Fail
Lmax	6 fL min ± 4%	6.09fL$^{(Z)}$, 7.05fL $^{(IR)}$	Pass	5.1fL$^{(Z)}$, 6.0fL $^{(IR)}$	Fail
Dynamic range	17.7 dB min	17.6dB$^{(Z)}$,18.5dB $^{(IR)}$	Pass	20.0dB$^{(Z)}$, 20.1dB $^{(IR)}$	Pass
Uniformity (Chromaticity)	0.02 ± 0.005 Δu'v' max	0.006 Δu'v'	Pass	0.006 Δu'v'	Pass
Refresh rate	60 Hz per eye, min	60.5 Hz per eye	Pass	60.0 Hz per eye	Pass
Extinction Ratio	15:1 min	12.5:1 $^{(Z)}$, 25:7 $^{(IR)}$	Pass	11:1 $^{(Z)}$, 18:7 $^{(IR)}$	Pass

$^{(Z)}$ Denotes StereoGraphics ZScreen and Eyewear $^{(IR)}$ Denotes StereoGraphics CrystalEyes IR Eyewear

Section I INTRODUCTION

The National Information Display Laboratory (NIDL) was established in 1990 to bring together technology providers - commercial and academic leaders in advanced display hardware, softcopy information processing tools, and information collaboration and communications techniques - with government users. The Sarnoff Corporation in Princeton, New Jersey, a world research leader in high-definition digital TV, advanced displays, computing and electronics, hosts the NIDL.

The present study evaluates a production unit of the Cornerstone p1750 color CRT high-resolution display monitor. This report is intended for both technical users, such as system integrators, monitor designers, and monitor evaluators, and non-technical users, such as image analysts, software developers, or other users unfamiliar with detailed monitor technology.

The IEC requirements, procedures and calibrations used in the measurements are detailed in the following:

- *NIDL Publication No. 0201099-091*, *Request for Evaluation Monitors for the National Imagery & Mapping Agency (NIMA) Integrated Exploitation Capability (IEC),* August 25, 1999.

Two companion documents that describe how the measurements are made are available from the NIDL and the Defense Technology Information Center at http://www.dtic.mil:

- *NIDL Publication No. 171795-036 Display Monitor Measurement Methods under Discussion by EIA (Electronic Industries Association) Committee JT-20 Part 1: Monochrome CRT Monitor Performance Draft Version 2.0. (ADA353605)*
- *NIDL Publication No. 171795-037 Display Monitor Measurement Methods under Discussion by EIA (Electronic Industries Association) Committee JT-20 Part 2: Color CRT Monitor Performance Draft Version 2.0. (ADA341357)*

Other procedures are found in a recently approved standard available from the Video Electronics Standards Association (VESA) at http://www.vesa.org:

- *VESA Flat Panel Display Measurements Standard, Version 2.0, June 1, 2001.*

The IEC workstation provides the capability to display image and other geospatial data on either monochrome or color monitors, or a combination of both. Either of these monitors may be required to support stereoscopic viewing. Selection and configuration of these monitors will be made in accordance with mission needs for each site. NIMA users will select from monitors included on the NIMA-approved Certified Monitor List compiled by the NIDL. The color and monochrome, monoscopic and stereoscopic, monitor requirements are listed in the Evaluation Datasheet.

I.1. Manufacturer's Specifications for the Cornerstone p1750 Monitor

The identification tag located on the rear panel of the Cornerstone p1750 monitor supplied by the manufacturer contained the following information:

Model No. AT320DB
Part No. p17501-990/991
Assembly No. 4614503-001
Lot No. A
Manufactured August/Aug. 2001
Serial No. 126113200031
Made in Taiwan (Amtran)
1936-110-3200

Specifications provided by manufacturer

- **22 inch diagonal, 19.9 inch viewable Mitsubishi natural flat CRT**
- **2048 x 1536 pixels at 80 Hz**
- **30 to 127 kHz horizontal scan frequency**
- **50 to 180 Hz**
- **0.25 mm horizontal aperture pitch**
- **Pixel clock 335 MHz**
- **Luminance 95 candelas/m2**
- **Color presets 5000, 6500, 9300K**
- **Weight 72.2 pound**
- **Voltage 100 to 240 V AC 50-60 Hz**
- **Power 150 W**
- **Heat dissipation 512 BTU/hour**
- **Operating temperature 32 to 104 F**
- **Operating humidity 10 to 90%**

I.2. Initial Monitor Set Up

Reference: Request for Evaluation Monitors, NIDL Pub. 0201099-091, Section 5, p 5.

All measurements will be made with the display commanded through a laboratory grade programmable test pattern generator. The system will be operated in at least a 24 bit mode (as opposed to a lesser or pseudo-color mode) for color and at least 8 bits for monochrome. As a first step, refresh rate should be measured and verified to be at least 72 Hz. The screen should then be commanded to full addressability and Lmin set to 0.1 fL. Lmax should be measured at screen center with color temperature between D65 and D93 allowable and any operator adjustment of gain allowable. If a value >35fL is not achieved (>30 fL for color), addressability should be lowered. For a nominal 1200 by 1600 addressability, addressability should be lowered to 1280 by 1024 or to 1024 by 1024. For a nominal 2048 by 2560 addressability, addressabilities of 1200 x 1600 and 1024 x 1024 can be evaluated if the desired Lmax is not achieved at full addressability.

I.3. Equipment

Reference: Monochrome CRT Monitor Performance, Draft Version 2.0 Section 2.0, page 3.

The procedures described in this report should be carried out in a darkened environment such that the stray luminance diffusely reflected by the screen in the absence of electron-beam excitation is less than 0.003 cd/m^2 (1mfL).

Instruments used in these measurements included:

- Quantum Data 8701 400 MHz programmable test pattern signal generator
- Photo Research SpectraScan PR-650 spectroradiometer
- Photo Research SpectraScan PR-704 spectroradiometer
- Minolta LS-100 Photometer
- Minolta CA-100 Colorimeter
- Graseby S370 Illuminance Meter
- Microvision Superspot 100 Display Characterization System which included OM-1 optic module (Two Dimensional photodiode linear array device, projected element size at screen set to 1.3 mils with photopic filter) and Spotseeker 4-Axis Positioner

Stereoscopic-mode measurements were made using the following commercially-available stereo products:

- StereoGraphics ZScreen 19-inch LCD shutter with passive polarized eyeglasses.
- StereoGraphics CrystalEyes IR Eyewear.

Section II PHOTOMETRIC MEASUREMENTS

II.1. Dynamic Range and Screen Reflectance

References: *Request for Evaluation Monitors, NIDL Pub. 0201099-091, Section 5.6, p 6.*

VESA Flat Panel Display Measurements Standard, Version 1.0, May 15, 199, Section 308-1.

Full screen white-to-black contrast ratio measured in 1600 x 1200 format is 304:1 (24.8 dB dynamic range) in a dark room and exceeds the IEC specification. We measured a screen reflectance of 5.2%, which is fairly low. In spite of this average-to-low reflectivity, the contrast ratio decreases to 149:1 (21.7 dB) in 2 fc diffuse ambient illumination. The absolute threshold for IEC is 22 dB. Thus, the strong influence of ambient light on the achievable contrast ratio is shown. To realize the highest contrast ratio, the amount of light falling on the screen should be minimized by turning off overhead florescent lights and substituting indirect reflected light from a wall wash.

Objective: Measure the photometric output (luminance vs. input command level) at Lmax and Lmin in both dark room and illuminated ambient conditions.

Equipment: Photometer, Integrating Hemisphere Light Source or equivalent

Procedure: Luminance at center of screen is measured for input counts of 0 and Max Count. Test targets are full screen (flat fields) where full screen is defined addressability. Set Lmin to 0.1 fL. For color monitors, set color temperature between D_{65} to D_{93}. Measure Lmax.

This procedure applies when intended ambient light level measured at the display is 2fc or less. For conditions of higher ambient light level, Lmin and Lmax should be measured at some nominal intended ambient light level (e.g., 18-20 fc for normal office lighting with no shielding). This requires use of a remote spot photometer following procedures outlined in reference 2, paragraph 308-2. This will at best be only an approximation since specular reflections will not be captured. A Lmin > 0.1 fL may be required to meet grayscale visibility requirements.

According to the VESA directed hemispherical reflectance (DHR) measurement method, total combined reflections due to specular, haze and diffuse components of reflection arising from uniform diffuse illumination are simultaneously quantified as a fraction of the reflectance of a perfect white diffuse reflector using the set up depicted in figure II.1-1. Total reflectance was calculated from measured luminances reflected by the screen (display turned off) when uniformly illuminated by an integrating hemisphere simulated using a polystyrene icebox.

Luminance is measured using a spot photometer with 1° measurement field and an illuminance sensor as depicted in Figure II.1-1. The measured values and calculated reflectances are given in Table II.1-1.

Data: Contrast ratio is a linear expression of Lmax to Lmin. Dynamic range expresses the contrast ratio in log units, dB, which correlates more closely with the sensitivity of the human vision system.

Define contrast ratio by: CR = Lmax/Lmin

Define dynamic range by: DR = 10log(Lmax/Lmin)

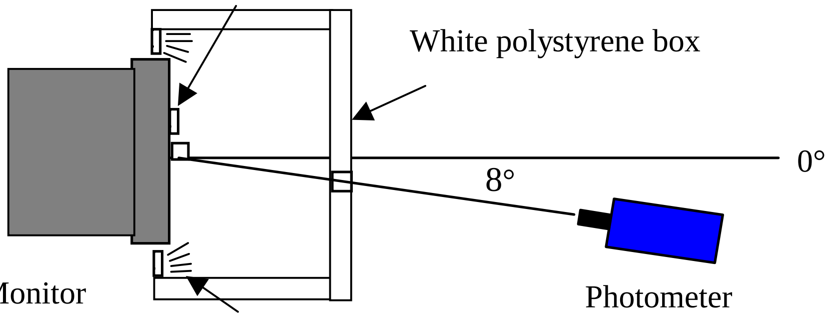


Figure II.1-1. Test setup according to VESA FPDM procedures for measuring total reflectance of screen.

Table II.1-1. Directed Hemispherical Reflectance of Faceplate

VESA ambient contrast illuminance source (polystyrene box)

Ambient Illuminance	18.6 fc
Reflected Luminance	0.973 fL
Faceplate Reflectance	5.2 %

Ambient dynamic ranges of full screen white-to-black given in Table II.1-2 were computed for various levels of diffuse ambient lighting using the measured value for DHR and the darkroom dynamic range measurements. Full screen white-to-black contrast ratio decreases from 304:1 (24.8 dB dynamic range) in a dark room to 149:1 (21.7 dB) in 2 fc diffuse ambient illumination. The absolute threshold for IEC is 158:1 (22 dB).

Table II.1-2. Dynamic Range in Dark and Illuminated Rooms

Effect of ambient lighting on dynamic range is calculated by multiplying the measured CRT faceplate reflectivity times the ambient illumination measured at the CRT in foot candles added to the minimum screen luminance, Lmin, where Lmin = 0.10.

Ambient Illumination	Contrast Ratio	Dynamic Range, dB
0 fc (Dark Room)	304 :1	24.8 dB
1 fc	200 :1	23.0 dB
2 fc	149 :1	21.7 dB
3 fc	119 :1	20.8 dB
4 fc	99 :1	20.0 dB
5 fc	85 :1	19.3 dB
6 fc	74 :1	18.7 dB
7 fc	66 :1	18.2 dB
8 fc	59 :1	17.7 dB
9 fc	54 :1	17.3 dB
10 fc	50 :1	17.0 dB
11 fc	46 :1	16.6 dB
12 fc	43 :1	16.3 dB
13 fc	40 :1	16.0 dB
14 fc	37 :1	15.7 dB
15 fc	35 :1	15.5 dB

II.2. Maximum Luminance (Lmax) in Monoscopic and Stereo Modes

References: Request for Evaluation Monitors, NIDL Pub. 0201099-091, Section 5.2, p 6.

The luminance for Lmax was set to 30.4 fL measured at screen center in 1600 x 1200 monoscopic format and meets the IEC specification of 30 fL. In the 1024 x 1024 stereoscopic mode through the ZScreen and passive glasses, it averages 5.1 fL between left and right eyes and fails to meet the IEC specification of 6 fL for Lmax. With stereo active glasses, Lmax averages 6.0 fL.

Objective: Measure the maximum output display luminance.

Equipment: Photometer

Procedure: See dynamic range. Use the value of Lmax defined for the Dynamic Range measurement.

Data: The maximum output display luminance, Lmax, and associated CIE x, y chromaticity coordinates (CIE 1976) were measured using a hand-held colorimeter (Minolta CA-100). The correlated color temperature (CCT) computed from the measured CIE x, y chromaticity coordinates was within range specified by IEC (6500K and 9300K).

Table II.2-1. Maximum Luminance and Color

Color and luminance (in fL) for full screen at 100% Lmax taken at screen center.

Format	Mode	CCT	CIE x	CIE y	Luminance
1600 x 1200 x 75 Hz	Monoscopic	9830 K	0.276	0.299	30.4 fL
1024 x 1024 x 120 Hz	Stereoscopic (1)				
	Left Eye	9213 K	0.267	0.335	4.81 fL
	Right Eye	8792 K	0.276	0.328	5.38 fL
	Stereoscopic (2)				
	Left Eye	9839 K	0.266	0.319	5.94 fL
	Right Eye	9567 K	0.268	0.322	6.04 fL

(1) Measured luminance through ZScreen and stereo passive glasses
(2) Measured luminance through stereo active LC shutter glasses.

II.3. Luminance at Lmax and Color Uniformity

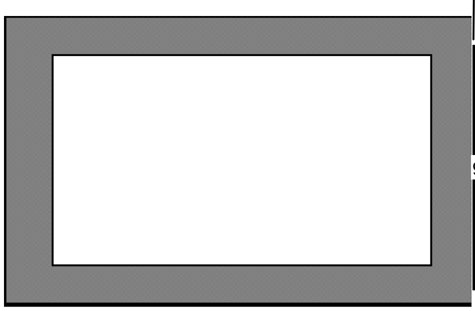
Reference: Monochrome CRT Monitor Performance, Draft Version 2.0, Section 4.4, p. 28.

Maximum luminance (Lmax) varied by 10.7% across the screen, well below the IEC maximum value of 20%. Chromaticity variations were 0.005 delta u'v' units or less, or about a factor of 2 lower than allowed by the IEC specification.

Objective: Measure the variability of luminance and chromaticity coordinates of the white point at 100% Lmax only and as a function of spatial position. Variability of luminance impacts the total number of discriminable gray steps.

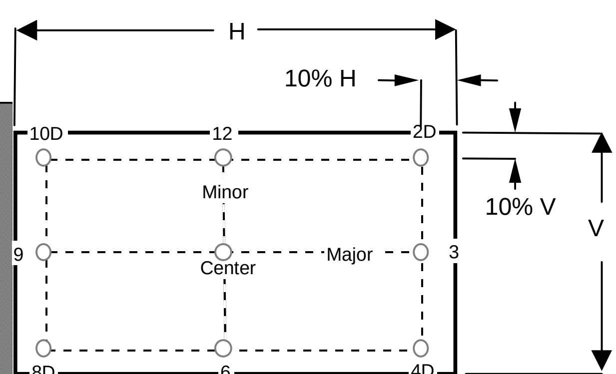
Equipment:
- Video generator
- Photometer
- Spectroradiometer or Colorimeter

Test Pattern: Full screen flat field with visible edges at L_{min} as shown in Figure II.3-1.



Full Screen Flat Field test pattern.

Figure II.3-1



Nine screen test locations.

Figure II.3-2

Procedure: Investigate the temporal variation of luminance and the white point as a function of intensity by displaying a full flat field shown in Figure II.3-1 for video input count levels corresponding L_{max}. Measure the luminance and C.I.E. color coordinates at center screen.

Investigate the temporal variation of luminance and the white point as a function of spatial position by repeating these measurements at each of the locations depicted in Figure II.3-2. Define color uniformity in terms of $\Delta u'v'$.

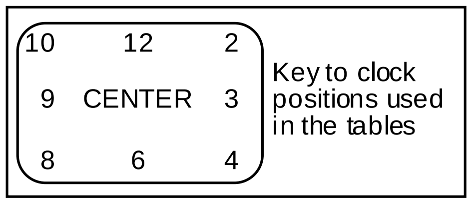
Data: Tabulate the luminance and 1931 C.I.E. chromaticity coordinates (x, y) or correlated color temperature of the white point at each of the nine locations depicted in Figure II.3-2. Additionally, note the location of any additional points that are measured along with the corresponding luminance values.

Table II.3-1.Spatial Uniformity of Luminance and Color

Color and luminance (in fL) for Full screen at 100% Lmax taken at nine screen positions.

1600 x 1200

POSITION	CCT	CIE x	CIE y	L, fL
center	9830	0.276	0.299	30.4
2	10430	0.272	0.295	30.4
3	10267	0.272	0.298	28.8
4	9878	0.275	0.300	28.4
6	10168	0.273	0.298	30.9
8	9926	0.276	0.297	29.2
9	10498	0.273	0.292	30.1
10	10122	0.274	0.297	30.9
12	9974	0.275	0.298	31.8



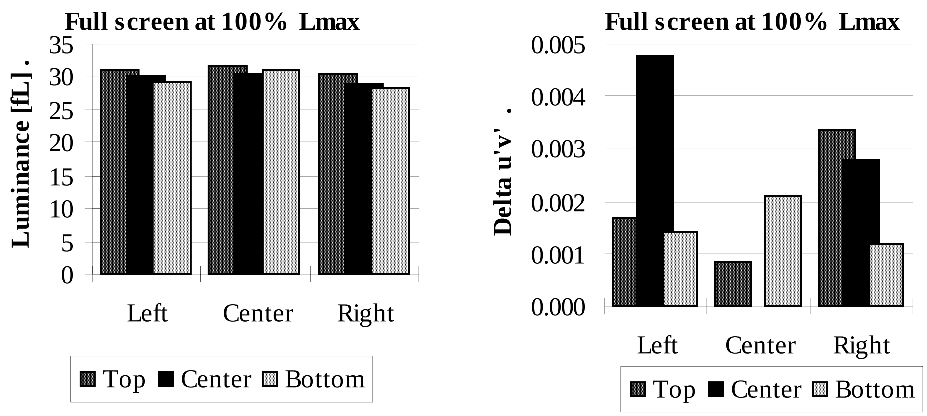


Fig.II.3-3. Spatial Uniformity of Luminance and Chromaticity at Lmax. (Delta u'v' of 0.004 is just visible.)

II.4. Halation

Reference: Monochrome CRT Monitor Performance, Draft Version 2.0 Section 4.6, page 48.

Halation was 6.55% +/- 0.5% on a small black patch surrounded by a large full white area, and failed to meet the IEC specification of 3.5%. This higher value may impact IA and GI task performance.

Objective: Measure the contribution of halation to contrast degradation. Halation is a phenomenon in which the luminance of a given region of the screen is increased by contributions from surrounding areas caused by light scattering within the phosphor layer and internal reflections inside the glass faceplate. The mechanisms that give rise to halation, and its detailed non-monotonic dependence on the distance along the screen between the source of illumination and the region being measured have been described by E. B. Gindele and S.L. Shaffer. The measurements specified below determine the percentage of light that is piped into the dark areas as a function of the extent of the surrounding light areas.

Equipment:
- Photometer
- Video generator

Test Pattern:

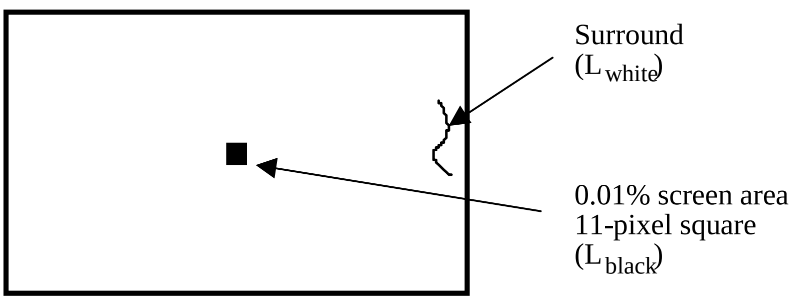


Figure II.4-1 *Test pattern for measuring halation.*

Procedure: Note: The halation measurements require changing the setting of the BRIGHTNESS control and will perturb the values of L_{max} and L_{min} that are established during the initial monitor set-up. The halation measurements should therefore be made either first, before the monitor setup, or last, after all other photometric measurements have been completed.

Determine halation by measuring the luminance of a small square displayed at L_{black} (essentially zero) and at L_{white} when surrounded by a much larger square displayed at L_{white} (approximately 75% L_{max}).

Establish L_{black} by setting the display to cutoff. To set the display to cut-off, display a flat field using video input count level zero, and use a photometer to monitor the luminance at center screen. Vary the BRIGHTNESS control until the CRT beam is visually cut off, and confirm that the corresponding luminance

(L_{stray}) is essentially equal to zero. Fine tune the BRIGHTNESS control such that CRT beam is just on the verge of being cut off. These measurements should be made with a photometer that is sensitive at low light levels (below L_{min} of the display). Make no further adjustments or changes to the BRIGHTNESS control or the photometer measurement field.

Next, decrease the video-input level to display a measured full-screen luminance of 75% L_{max} measured at screen center. Record this luminance (L_{white}).

The test target used in the halation measurements is a black (L_{black}) square patch of width equal to 0.01% of the area of addressable screen, the interior square as shown in Figure II.4-1. The interior square patch is enclosed in a white (L_{white}) background encompassing the remaining area of the image. The exterior surround will be displayed at 75% L_{max} using the input count level for L_{white} as determined above. The interior square will be displayed at input digital count level zero.

Care must be taken during the luminance measurement to ensure that the photometer's measurement field is less than one-half the size of the interior square and is accurately positioned not to extend beyond the boundary of the interior square. The photometer should be checked for light scattering or lens flare effects which allow light from the surround to enter the photosensor. A black card with aperture equal to the measurement field (one-half the size of the interior black square) may be used to shield the photometer from the white exterior square while making measurements in the interior black square.

Analysis: Compute the percent halation for each test target configuration. Percent halation is defined as:

$$\% \text{ Halation} = L_{black} \,/\, (L_{white} - L_{black}) \times 100$$

Where, L_{black}= measured luminance of interior square displayed at L_{black} using input count level zero,

L_{white}= measured luminance of interior square displayed at L_{white} using input count level determined to produce a full screen luminance of 75% L_{max} .

Data: Table II.4-1 contains measured values of L_{black}, L_{white} and percentage halation.

Table II.4-1 Halation for 1600 x 1200 Addressability

	Reported Values	Range for 4% uncertainty
Lblack	1.31 fL ± 4%	1.26 fL to 1.36 fL
Lwhite	20.02 fL ± 4%	19.22 fL to 20.82 fL
Halation	6.55% ± 0.5%	6.05% to 7.10%

II.5. Color Temperature

Reference: Monochrome CRT Monitor Performance, Draft Version 2.0 Section 5.4, page 22.

The CCT of the measured white point was user-adjusted to 9830 K to achieve +/- 0.010 Δu'v' boundary accepted by IEC. For a 9300 K preset, the CCT is 8811 K.

Objective: Insure measured screen white of a color monitor has a correlated color temperature (CCT) between 6500K and 9300K.

Equipment: Colorimeter

Procedure: Command screen to Lmax. Measure u'v' chromaticity coordinates (CIE 1976).

Data: Coordinates of screen white should be within 0.01 Δu'v' of the corresponding CIE daylight, which is defined as follows: If the measured screen white has a CCT between 6500 and 9300 K, the corresponding daylight has the same CCT as the screen white. If the measured CCT is greater than 9300 K, the corresponding daylight is D93. If the measured CCT is less than 6500 K, the corresponding daylight is D65. The following equations were used to compute Δu'v' values listed in table II.5.1:

1. Compute the correlated color temperature (CCT) associated with (x,y) by the VESA/McCamy formula: CCT = 437 n^3 + 3601 n^2 + 6831 n + 5517, where n = (x-0.3320)/(0.1858 - y). [This is on p. 227 of the FPDM standard]

2. If CCT < 6500, replace CCT by 6500. If CCT > 9300, replace CCT by 9300.

4. Use formulas 5(3.3.4) and 6(3.3.4) in Wyszecki and Stiles (pp.145-146 second edition) to compute the point (xd,yd) associated with CCT.
   - First, define u = 1000/CCT.
   - If CCT < 7000, then xd = -4.6070 u^3 + 2.9678 u^2 + 0.09911 u +
   - 0.244063.
   - If CCT > 7000, then xd = -2.0064 u^3 + 1.9018 u^2 + 0.24748 u +
   - 0.237040.
   - In either case, yd = -3.000 xd^2 + 2.870 xd -0.275.

5. Convert (x,y) and (xd,yd) to u'v' coordinates:
   - (u',v') = (4x,9y)/(3 + 12y - 2x)
   - (u'd,v'd) = (4xd,9yd)/(3 + 12yd - 2xd)

6. Evaluate delta-u'v' between (u,v) and (ud,vd):
   - delta-u'v' = sqrt[(u' - u'd)^2 + (v' - v'd)^2].

7. If delta-u'v' is greater than 0.01, display fails the test. Otherwise it passes the test.

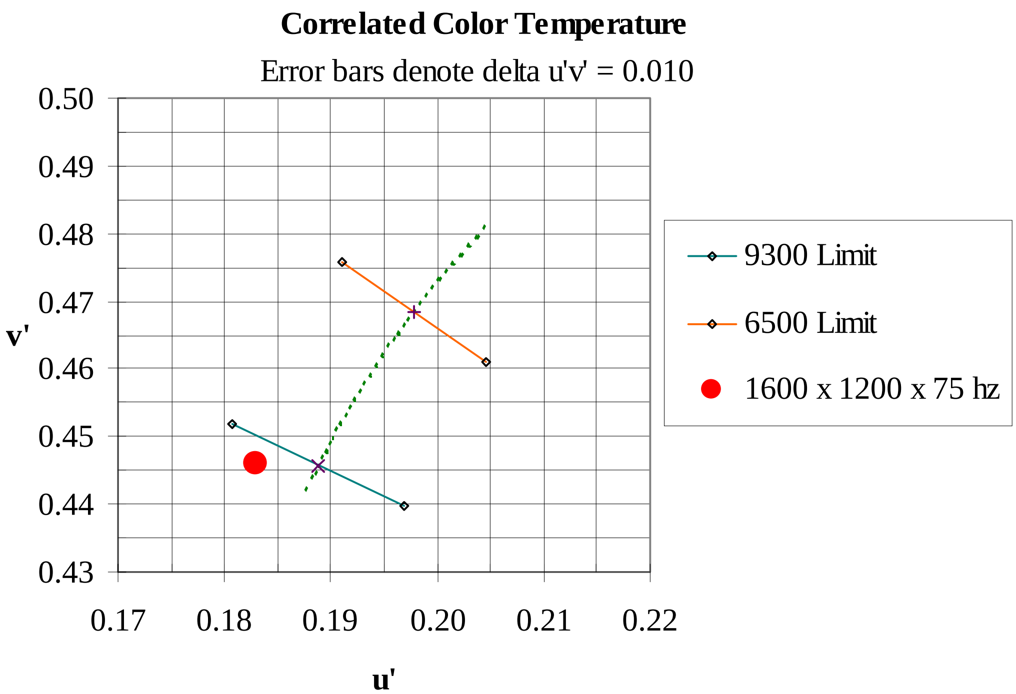


Figure II.5-1 *The CCT of the measured white point is within the boundaries required by IEC.*

Table II.5-1 Δu'v' Distance between the measured white point and CIE coordinate values.

	1600 x 1200
CIE x	0.276
CIE y	0.299
CIE u'	0.183
CIE v'	0.446
CCT	9830
delta u'v'	**0.006**

II.6. Bit Depth

Reference: Request for Evaluation Monitors, NIDL Pub. 0201099-091, Section 5.6, p 6.

Positive increases in luminance were measured for each of the 256 input levels for 8 bits of gray scale. Between one and four JNDs separated each level. Neither black level clipping nor white level saturation was observed) for input counts 0 to 255 with front panel contrast control set to maximum.

Objective: Measure the number of bits of data that can be displayed as a function of the DAC and display software.

Equipment: Photometer

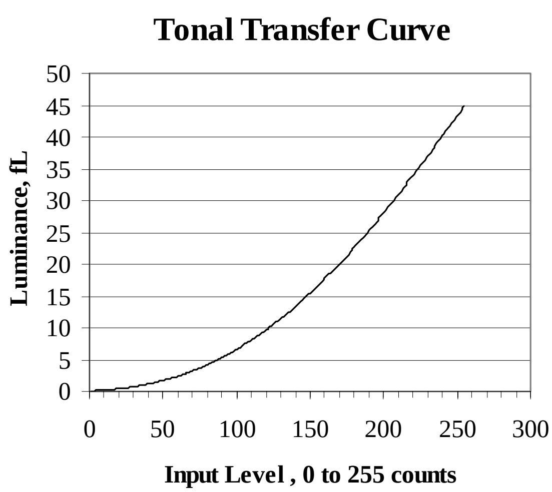
Test targets: Targets are n four inch patches with command levels of all commandable levels; e.g., 256 for 8 bit display. Background is commanded to 0.5* ((0.7 *P)+0.3*n) where P = patch command level, n = number of command levels.

Procedure: Measure patch center for all patches with Lmin and Lmax as defined previously. Count number of monotonically increasing luminance levels. Use the NEMA/DICOM model to define discriminable luminance differences. For color displays, measure white values.

Data: Define bit depth by $\log_2$ (number of discrete luminance levels)

The number of bits of data that can be displayed as a function of the input signal voltage level were verified through measurements of the luminance of white test targets displayed using a Quantum Data 8701 test pattern generator and a Minolta CA-100 colorimeter. Targets are n four-inch patches with command levels of all commandable levels; e.g., 256 for 8 bit display. Background is commanded to 0.5* ((0.7 *P)+0.3*n) where P = patch command level, n = number of command levels. The NEMA/DICOM model was used to define discriminable luminance differences in JNDs.

Figure II.6-1 shows the System Tonal Transfer curve and the perceptibility of gray level step sizes in Just Noticeable Differences (JNDs) as a function of input counts measured at screen center. The data for each of the 256 levels are listed in Table II.6-1.



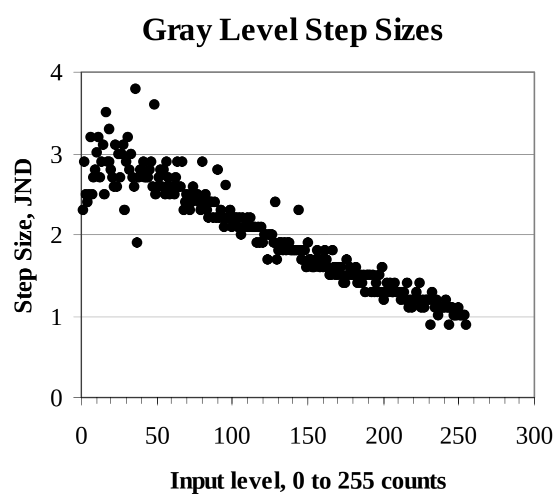


Figure II.6-1. System Tonal Transfer and perceptibility of gray level step sizes in Just Noticeable Differences (JNDs) for input counts 0 to 255 with front panel contrast control set to maximum.

Table II.6-1. System Tonal Transfer for input counts 0 to 127 with front panel contrast control set to maximum.

Background	Target	L, fL	Diff, fL	Diff, JND	Background	Target	L, fL	Diff, fL	Diff, JND
38	0	0.087	0	0.0	61	64	2.706	0.091	2.9
39	1	0.095	0.008	2.3	61	65	2.788	0.082	2.6
39	2	0.106	0.011	2.9	62	66	2.871	0.083	2.6
39	3	0.116	0.01	2.5	62	67	2.968	0.097	2.9
40	4	0.126	0.01	2.4	62	68	3.047	0.079	2.3
40	5	0.137	0.011	2.5	63	69	3.129	0.082	2.4
41	6	0.152	0.015	3.2	63	70	3.216	0.087	2.5
41	7	0.164	0.012	2.5	63	71	3.302	0.086	2.4
41	8	0.178	0.014	2.7	64	72	3.389	0.087	2.3
42	9	0.193	0.015	2.8	64	73	3.479	0.09	2.4
42	10	0.21	0.017	3.0	64	74	3.577	0.098	2.6
42	11	0.229	0.019	3.2	65	75	3.672	0.095	2.5
43	12	0.246	0.017	2.7	65	76	3.774	0.102	2.5
43	13	0.265	0.019	2.9	65	77	3.876	0.102	2.5
43	14	0.286	0.021	3.1	66	78	3.972	0.096	2.4
44	15	0.304	0.018	2.5	66	79	4.071	0.099	2.3
44	16	0.33	0.026	3.5	66	80	4.194	0.123	2.9
44	17	0.353	0.023	2.9	67	81	4.299	0.105	2.4
45	18	0.376	0.023	2.9	67	82	4.41	0.111	2.5
45	19	0.404	0.028	3.3	67	83	4.518	0.108	2.3
45	20	0.429	0.025	2.8	68	84	4.62	0.102	2.2
46	21	0.454	0.025	2.7	68	85	4.731	0.111	2.4
46	22	0.479	0.025	2.6	69	86	4.846	0.115	2.4
46	23	0.509	0.03	3.1	69	87	4.954	0.108	2.2
47	24	0.536	0.027	2.6	69	88	5.073	0.119	2.4
47	25	0.568	0.032	3.0	70	89	5.189	0.116	2.2
48	26	0.597	0.029	2.7	70	90	5.332	0.143	2.8
48	27	0.631	0.034	3.0	70	91	5.446	0.114	2.2
48	28	0.667	0.036	3.1	71	92	5.569	0.123	2.3
49	29	0.696	0.029	2.3	71	93	5.688	0.119	2.2
49	30	0.732	0.036	2.9	71	94	5.811	0.123	2.2
49	31	0.773	0.041	3.2	72	95	5.934	0.123	2.1
50	32	0.81	0.037	2.8	72	96	6.082	0.148	2.6
50	33	0.852	0.042	3.0	72	97	6.208	0.126	2.2
50	34	0.89	0.038	2.7	73	98	6.342	0.134	2.2
51	35	0.929	0.039	2.6	73	99	6.477	0.135	2.3
51	36	0.986	0.057	3.8	73	100	6.605	0.128	2.1
51	37	1.016	0.03	1.9	74	101	6.748	0.143	2.2
52	38	1.059	0.043	2.7	74	102	6.882	0.134	2.2
52	39	1.105	0.046	2.8	74	103	7.028	0.146	2.2
52	40	1.152	0.047	2.8	75	104	7.165	0.137	2.1
53	41	1.203	0.051	2.9	75	105	7.308	0.143	2.2
53	42	1.252	0.049	2.7	76	106	7.448	0.14	2.0
53	43	1.302	0.05	2.7	76	107	7.597	0.149	2.2
54	44	1.352	0.05	2.7	76	108	7.743	0.146	2.1
54	45	1.407	0.055	2.8	77	109	7.892	0.149	2.1
55	46	1.464	0.057	2.9	77	110	8.047	0.155	2.2
55	47	1.518	0.054	2.6	77	111	8.202	0.155	2.1
55	48	1.593	0.075	3.6	78	112	8.368	0.166	2.2
56	49	1.648	0.055	2.5	78	113	8.523	0.155	2.1
56	50	1.707	0.059	2.6	78	114	8.686	0.163	2.1
56	51	1.768	0.061	2.7	79	115	8.852	0.166	2.1
57	52	1.833	0.065	2.8	79	116	9.001	0.149	1.9
57	53	1.895	0.062	2.6	79	117	9.168	0.167	2.1
57	54	1.963	0.068	2.8	80	118	9.325	0.157	1.9
58	55	2.028	0.065	2.5	80	119	9.491	0.166	2.1
58	56	2.094	0.066	2.6	80	120	9.652	0.161	1.9
58	57	2.169	0.075	2.9	81	121	9.824	0.172	2.0
59	58	2.242	0.073	2.7	81	122	9.994	0.17	2.0
59	59	2.313	0.071	2.5	81	123	10.14	0.146	1.7
59	60	2.387	0.074	2.6	82	124	10.32	0.18	2.0
60	61	2.461	0.074	2.6	82	125	10.5	0.18	2.0
60	62	2.534	0.073	2.5	83	126	10.68	0.18	2.0
60	63	2.615	0.081	2.7	83	127	10.86	0.18	1.9

Table II.6-2. System Tonal Transfer for input counts 128 to 255 with front panel contrast control set to maximum.

Background	Target	L, fL	Diff, fL	Diff, JND
83	128	11.08	0.22	2.4
84	129	11.24	0.16	1.7
84	130	11.41	0.17	1.8
84	131	11.6	0.19	1.9
85	132	11.79	0.19	1.9
85	133	11.98	0.19	1.9
85	134	12.16	0.18	1.8
86	135	12.35	0.19	1.9
86	136	12.54	0.19	1.8
86	137	12.74	0.2	1.9
87	138	12.94	0.2	1.9
87	139	13.14	0.2	1.8
87	140	13.33	0.19	1.8
88	141	13.53	0.2	1.8
88	142	13.74	0.21	1.8
88	143	13.94	0.2	1.8
89	144	14.21	0.27	2.3
89	145	14.42	0.21	1.8
90	146	14.62	0.2	1.7
90	147	14.83	0.21	1.8
90	148	15.05	0.22	1.8
91	149	15.25	0.2	1.6
91	150	15.48	0.23	1.9
91	151	15.7	0.22	1.7
92	152	15.91	0.21	1.7
92	153	16.12	0.21	1.6
92	154	16.33	0.21	1.6
93	155	16.56	0.23	1.7
93	156	16.79	0.23	1.8
93	157	17.02	0.23	1.7
94	158	17.24	0.22	1.6
94	159	17.47	0.23	1.7
94	160	17.7	0.23	1.6
95	161	17.95	0.25	1.8
95	162	18.19	0.24	1.7
95	163	18.43	0.24	1.6
96	164	18.64	0.21	1.5
96	165	18.87	0.23	1.5
97	166	19.13	0.26	1.8
97	167	19.38	0.25	1.6
97	168	19.62	0.24	1.6
98	169	19.86	0.24	1.5
98	170	20.09	0.23	1.5
98	171	20.34	0.25	1.6
99	172	20.59	0.25	1.6
99	173	20.84	0.25	1.5
99	174	21.07	0.23	1.4
100	175	21.29	0.22	1.4
100	176	21.58	0.29	1.7
100	177	21.83	0.25	1.5
101	178	22.09	0.26	1.6
101	179	22.35	0.26	1.5
101	180	22.61	0.26	1.5
102	181	22.87	0.26	1.5
102	182	23.15	0.28	1.6
102	183	23.41	0.26	1.4
103	184	23.66	0.25	1.4
103	185	23.93	0.27	1.5
104	186	24.18	0.25	1.4
104	187	24.46	0.28	1.5
104	188	24.71	0.25	1.3
105	189	25	0.29	1.5
105	190	25.28	0.28	1.5
105	191	25.56	0.28	1.5
106	192	25.82	0.26	1.3
106	193	26.11	0.29	1.5
106	194	26.37	0.26	1.3
107	195	26.66	0.29	1.4
107	196	26.92	0.26	1.3
107	197	27.21	0.29	1.5
108	198	27.49	0.28	1.3
108	199	27.81	0.32	1.6
108	200	28.06	0.25	1.2
109	201	28.35	0.29	1.3
109	202	28.65	0.3	1.4
109	203	28.93	0.28	1.3
110	204	29.22	0.29	1.4
110	205	29.51	0.29	1.3
111	206	29.8	0.29	1.3
111	207	30.09	0.29	1.3
111	208	30.41	0.32	1.4
112	209	30.7	0.29	1.3
112	210	31	0.3	1.3
112	211	31.29	0.29	1.3
113	212	31.58	0.29	1.2
113	213	31.87	0.29	1.3
113	214	32.19	0.32	1.3
114	215	32.48	0.29	1.2
114	216	32.81	0.33	1.4
114	217	33.07	0.26	1.1
115	218	33.36	0.29	1.2
115	219	33.65	0.29	1.1
115	220	33.94	0.29	1.2
116	221	34.25	0.31	1.2
116	222	34.56	0.31	1.3
116	223	34.88	0.32	1.2
117	224	35.23	0.35	1.4
117	225	35.52	0.29	1.1
118	226	35.84	0.32	1.2
118	227	36.13	0.29	1.1
118	228	36.45	0.32	1.2
119	229	36.77	0.32	1.2
119	230	37.09	0.32	1.2
119	231	37.32	0.23	0.9
120	232	37.68	0.36	1.3
120	233	38	0.32	1.2
120	234	38.32	0.32	1.1
121	235	38.64	0.32	1.2
121	236	38.94	0.3	1.0
121	237	39.24	0.3	1.1
122	238	39.55	0.31	1.1
122	239	39.87	0.32	1.1
122	240	40.19	0.32	1.1
123	241	40.54	0.35	1.2
123	242	40.86	0.32	1.1
123	243	41.18	0.32	1.1
124	244	41.47	0.29	0.9
124	245	41.8	0.33	1.1
125	246	42.12	0.32	1.1
125	247	42.44	0.32	1.0
125	248	42.73	0.29	1.0
126	249	43.05	0.32	1.0
126	250	43.37	0.32	1.1
126	251	43.69	0.32	1.0
127	252	44.01	0.32	1.0
127	253	44.34	0.33	1.0
127	254	44.66	0.32	1.0
128	255	44.95	0.29	0.9

II.8. Luminance Step Response

Reference: Request for Evaluation Monitors, NIDL Pub. 0201099-091, Section 5.8, p 7.

No video artifacts were observed.

Objective: Determine the presence of artifacts caused by undershoot or overshoot.

Equipment: Test targets, SMPTE Test Pattern RP-133-1991, 2-D CCD array

Procedure: Display a center box 15% of screen size at input count levels corresponding to 25%, 50%, 75%, and 100% of Lmax with a surround of count level 0. Repeat using SMPTE Test pattern.

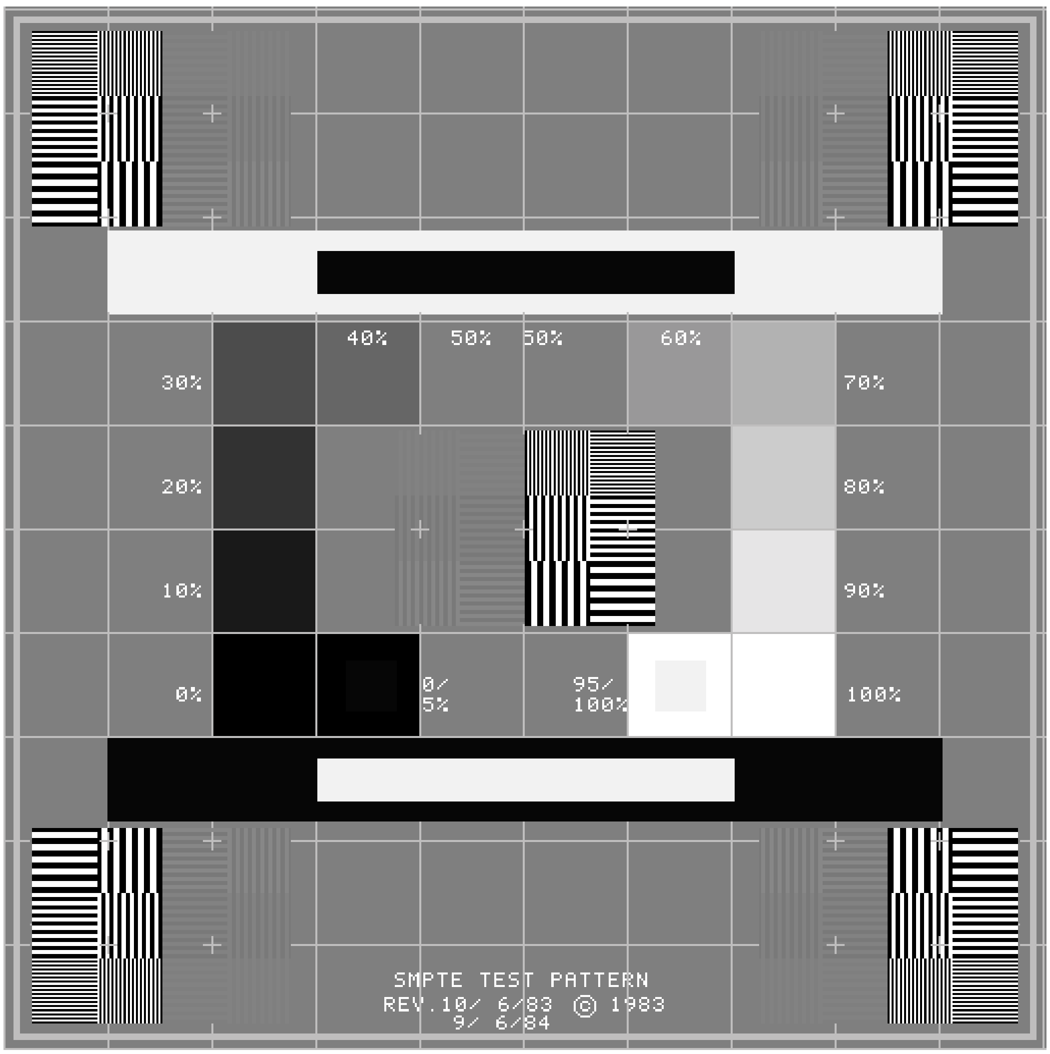


Figure II.8-1. SMPTE Test Pattern.

Data: Define passes by absence of noticeable ringing, undershoot, overshoot, or streaking.

The test pattern shown in Figure II.8-1 was used in the visual evaluation of the monitor. This test pattern is defined in SMPTE Recommended Practice RP-133-1986 published by the Society of Motion Picture and Television Engineers (SMPTE) for medical imaging applications. Referring to the large white-in-black and black-in-white horizontal bars contained in the test pattern, RP133-1986, paragraph 2.7 states " These areas of maximum contrast facilitate detection of mid-band streaking (poor low-frequency response), video amplifier ringing or overshoot, deflection interference, and halo." None of these artifacts was observed in the Cornerstone p1750 monitor, signifying good electrical performance of the video circuits.

II.9. Monoscopic and Stereoscopic Addressability

Reference: Monochrome CRT Monitor Performance, Draft Version 2.0, Section 6.1, page 67.

This monitor properly displayed all addressed pixels for the following tested formats (HxV): 1600 x 1200 x 75 Hz, monoscopic mode; 1024 x 1024 x 120 Hz, 1280 x 1024 x 118 Hz, stereoscopic mode.

Objective: Define the number of addressable pixels in the horizontal and vertical dimension; confirm that stated number of pixels is displayed.

Equipment: Programmable video signal generator.
Test pattern with pixels lit on first and last addressable rows and columns and on two diagonal lines beginning at upper left and lower right; H & V grill patterns 1-on/1-off.

Procedure: The number of addressed pixels were programmed into the Quantum Data 8701 test pattern generator for 85 Hz refresh rate which exceeds the 72 Hz minimum required by IEC for monoscopic mode and 120 Hz for stereoscopic mode, the minimum required by IEC. All perimeter lines were confirmed to be visible with no irregular jaggies on diagonals.

Data: If tests passed, number of pixels in horizontal and vertical dimension. If test fails, addressability unknown.

Table II.9-1 Addressabilities Tested

Monoscopic Mode	Stereoscopic Modes
1600 x 1200 x 75 Hz	1024 x 1024 x 120 Hz 1280 x 1024 x 118 Hz

II.10. Pixel Aspect Ratio

Reference: Request for Evaluation Monitors, NIDL Pub. 0201099-091, Section 5.10, p 8.

Pixel aspect ratio is within 0.3%.

Objective: Characterize aspect ratio of pixels.

Equipment: Test target, measuring tape with at least 1/16th inch increments

Procedure: Display box of 400 x 400 pixels at input count corresponding to 50% Lmax and background of 0. Measure horizontal and vertical dimension.

Alternatively, divide number of addressable pixels by the total image size to obtain nominal pixel spacings in horizontal and vertical directions.

Data: Define pass if H= V± 6% for pixel density <100 ppi and ± 10% for pixel density > 100 ppi.

Table II.10-1. Pixel Aspect Ratio

Addressability (H x V)	**1600 x 1200 full image**
H x V Image Size (inches)	15.234 x 11.463
H x V Average Pixel Spacing (mils)	9.52 x 9.55 mils
H x V Pixel Aspect Ratio	H = V + 0.3%

II.11. Screen Size (Viewable Active Image)

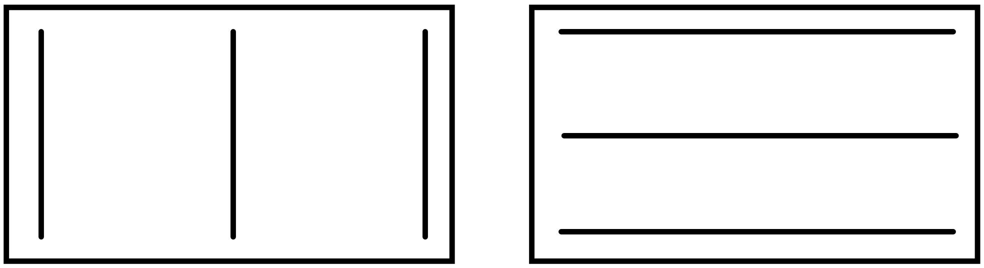
Reference: VESA Flat Panel Display Measurements Standard, Version 1.0, May 15, 1998, Section 501-1.

Image size for 1600 x 1200 format was 19.065 inches in diagonal.

Objective: Measure beam position on the CRT display to quantify width and height of active image size visible by the user (excludes any over scanned portion of an image).

Equipment:
- Video generator
- Spatially calibrated CCD or photodiode array optic module
- Calibrated X-Y translation stage

Test Pattern: Use the three-line grille patterns in Figure II.11-1 for vertical and horizontal lines each 1-pixel wide. Lines in test pattern are displayed at 100% L_{max} must be positioned along the top, bottom, and side edges of the addressable screen, as well as along both the vertical and horizontal centerlines (major and minor axes).



1-pixel-wide lines displayed at 100% L_{max}

Figure II.11-1 Three-line grille test patterns.

Procedure: Use diode optic module to locate center of line profiles in conjunction with calibrated X-Y translation to measure screen x,y coordinates of lines at the ends of the major and minor axes.

Data: Compute the image width defined as the average length of the horizontal lines along the top, bottom and major axis of the screen. Similarly, compute the image height defined as the average length of the vertical lines along the left side, right side, and minor axis of the screen. Compute the diagonal screen size as the square-root of the sum of the squares of the width and height.

Table II.11-1. Image Size

	Monoscopic Mode
Addressability (H x V)	1600 x 1200
H x V Image Size (inches) Diagonal Image Size (inches)	15.234 x 11.463 19.065

II.12. Contrast Modulation

Reference: Monochrome CRT Monitor Performance, Draft Version 2.0, Section 5.2, page 57.

Contrast modulation (Cm) for 1-on/1-off grille patterns displayed at 50% Lmax exceeded Cm = 60% in Zone A of diameter 7.6 inches, and Zone A diameter of 9.4 inches (40% of image area). Cm exceeded 54% in Zone B. Moiré cancellation circuitry was turned OFF for this measurement. These values substantially exceed the IEC specifications.

Objective: Quantify contrast modulation as a function of screen position.

Equipment:
- Video generator
- Spatially calibrated CCD or photodiode array optic module
- Photometer with linearized response

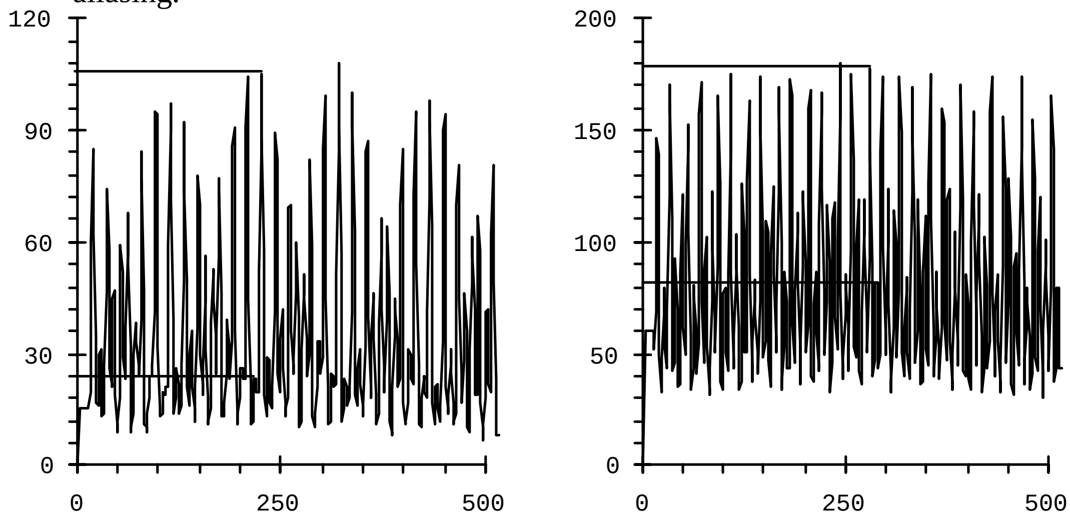
Procedure: The maximum video modulation frequency for each format (1024 x 1024, 1920 x 1200) was examined using horizontal and vertical grille test patterns consisting of alternating lines with 1 pixel on, 1 pixel off. Contrast modulation was measured in both horizontal and vertical directions at screen center and at eight peripheral screen positions. The measurements should be along the horizontal and vertical axes and along the diagonal from these axes. Use edge measurements no more than 10% of screen size in from border of active screen. The input signal level was set so that 1-line-on/1-line-off horizontal grille patterns produced a screen area-luminance of 25% of maximum level, Lmax.

Zone A is defined as a 24 degree subtended circle from a viewing distance of 18 inches (7.6 inch circle). Zone B is the remainder of the display. Use edge measurements no more than 10% of screen size in from border of active screen area to define Cm for Zone B (remaining area outside center circle). Determine Cm at eight points on circumference of circle by interpolating between center and display edge measurements to define Cm for Zone A. If measurements exceed the threshold, do not make any more measurements. If one or more measurements fail the threshold, make eight additional measurements at the edge (but wholly within) the defined circle.

Data: Values of vertical and horizontal Cm for Zone A and Zone B are given in Table II.12-1. The contrast modulation, Cm, is reported (the defining equation is given below) for the 1-on/1-off grille patterns.

$$C_m = \frac{L_{peak} - L_{valley}}{L_{peak} + L_{valley}}$$

The sample contrast modulations shown in Figure II.12-1 for two different color CRTs are not fully realized because of the presence of moiré caused by aliasing between the image and the shadow mask. Because contrast modulation values are calculated for the maximum peak and minimum valley luminance levels as indicated in the sample data shown, they do not include the degrading effects of aliasing.



Monitor A: 0.28mm dot pitch Monitor B: 0.26mm dot pitch

Figure II.12-1. *Contrast modulation for sample luminance profiles (1 pixel at input level corresponding to 50% Lmax, 1 pixel at level 0 = Lmin) for monitors exhibiting moiré due to aliasing.*

Table II.12-1. Contrast Modulation

Corrected for lens flare and Zone Interpolation
Moiré Cancellation OFF

Zone A = 7.6-inch diameter circle for 24-degree subtended circle at 18-inches viewing distance

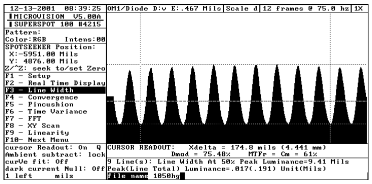
	Left				Minor				Right	
	H-grille	V-grille	H-grille	V-grille	H-grille	V-grille	H-grille	V-grille	H-grille	V-grille
Top	69%	87%			63%	90%			62%	90%
			69%	88%	65%	90%	66%	89%		
Major	69%	89%	69%	89%	69%	89%	62%	86%	54%	83%
			68%	88%	64%	90%	72%	87%		
Bottom	67%	88%			62%	91%			77%	85%

Zone A = 9.43-inch diameter circle for 40% area

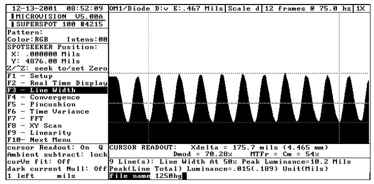
	Left				Minor				Right	
	H-grille	V-grille	H-grille	V-grille	H-grille	V-grille	H-grille	V-grille	H-grille	V-grille
Top	69%	87%			63%	90%			62%	90%
			69%	88%	64%	90%	66%	89%		
Major	69%	89%	69%	89%	69%	89%	60%	85%	54%	83%
			68%	88%	63%	91%	73%	87%		
Bottom	67%	88%			62%	91%			77%	85%

H-grille Luminance Profiles at 50% Lmax
For determining Contrast Modulation in the Vertical Direction

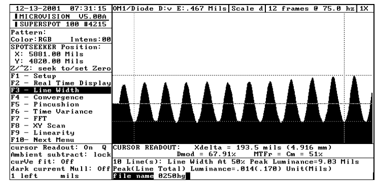
10:00 Corner



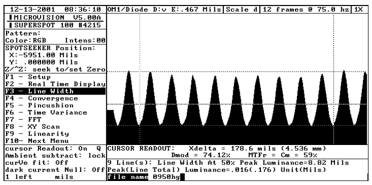
12:00



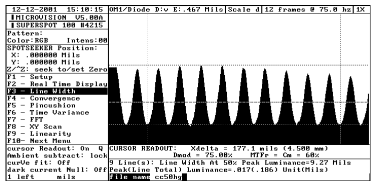
2:00 Corner



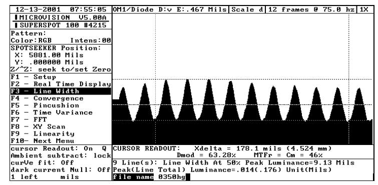
9:00



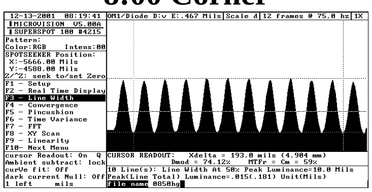
CENTER



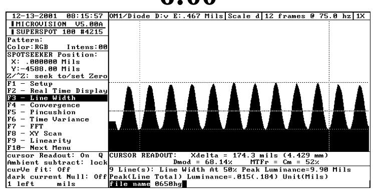
3:00



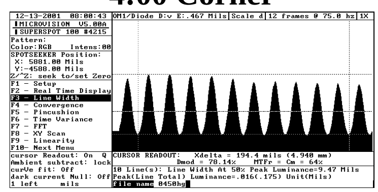
8:00 Corner



6:00

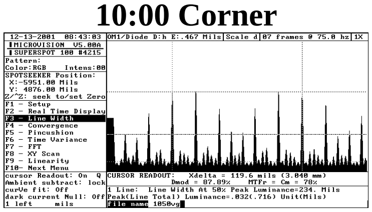


4:00 Corner

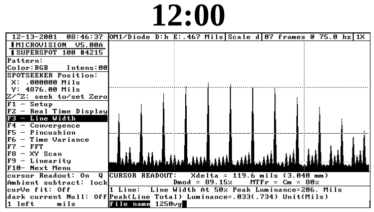


V-grille Luminance Profiles at 50% Lmax
For determining Contrast Modulation in the Horizontal Direction

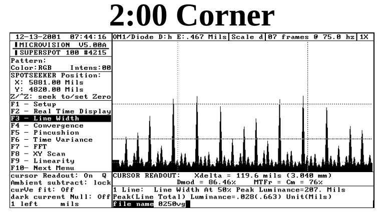
10:00 Corner



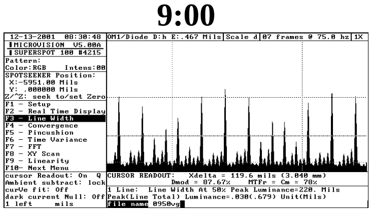
12:00



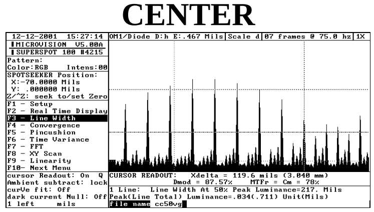
2:00 Corner



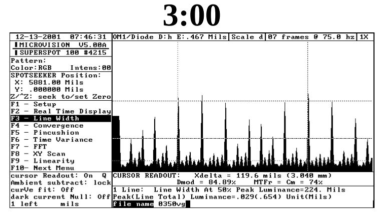
9:00



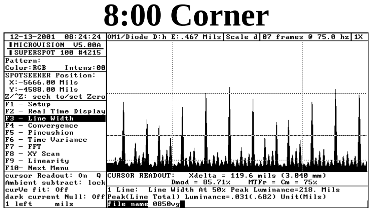
CENTER



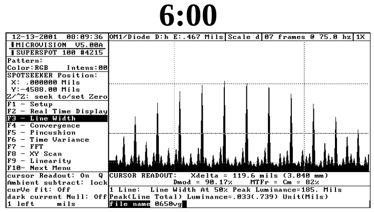
3:00



8:00 Corner



6:00



4:00 Corner

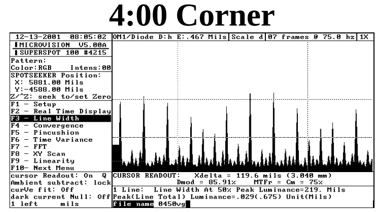
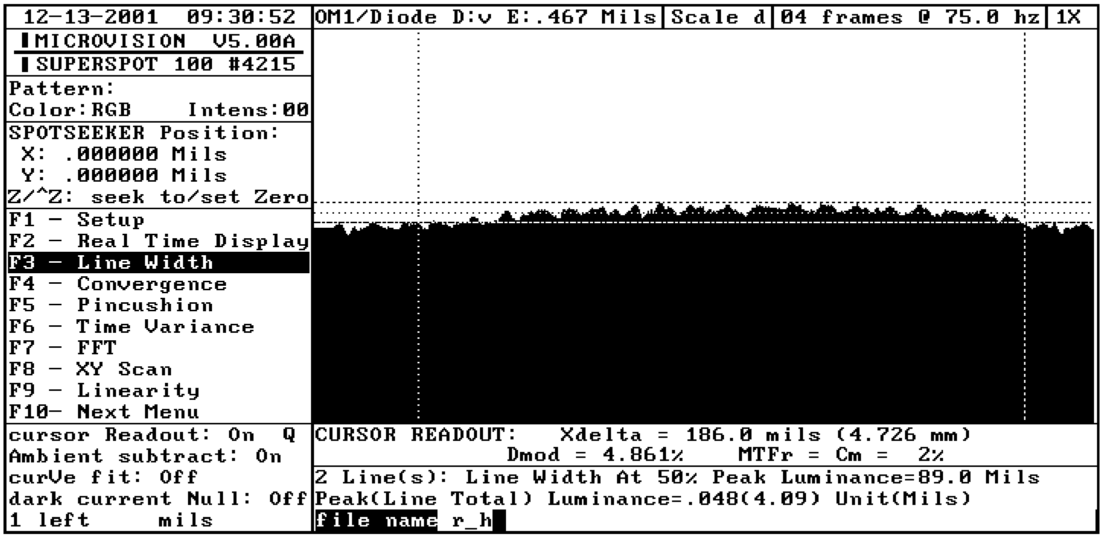


Figure II.12-2. *Measured luminance profiles for horizontal and vertical grille patterns (1 pixel at input level corresponding to 50% Lmax, 1 pixel at level 0 = Lmin) for the Cornerstone p1750 monitor. V-grilles exhibit extensive moiré due to aliasing.*

Contrast Modulation of White Full Screen

Raster Line Modulation Measured in Vertical Direction



Phosphor Stripe Contrast Measured in Horizontal Direction

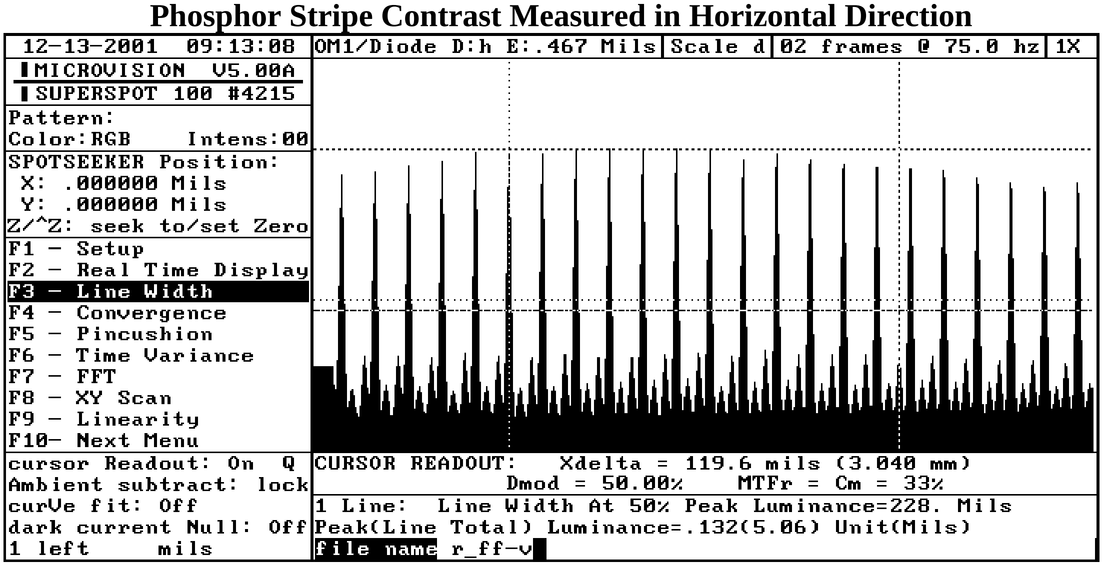


Figure II.12-3. *Measured luminance profiles for white full screen measured in the horizontal and vertical directions for the Cornerstone p1750 monitor.*

II.13. Pixel Density

Reference: Request for Evaluation Monitors, NIDL Pub. 0201099-091, Section 5.13, p 9.

Pixel density was 105 ppi as tested for the 1600 x 1200-line addressable format.

Objective: Characterize density of image pixels

Equipment: Measuring tape with at least 1/16 inch increments

Procedure: Measure H&V dimension of active image window and divide by vertical and horizontal addressability

Data: Define horizontal and vertical pixel density in terms of pixels per inch

Table II.13-1. Pixel-Density

	Monoscopic Mode
H x V Addressability, Pixels	1600 x 1200
H x V Image Size, Inches H x V Pixel Density, ppi	15.234 x 11.463 105 x 105 ppi

II.14. Moiré

Reference: Request for Evaluation Monitors, NIDL Pub. 0201099-091, Section 5.14, p 9.

Phosphor-to-pixel spacing ratio is 1.03 at screen center for the 1600 x 1200 format and fails the IEC specification of 1.0 maximum. Extensive Moiré patterns were observed. Moiré compensation circuitry was not evaluated.

Objective: Determine lack of moiré.

Equipment Loupe with scale graduated in 0.001 inch or equivalent

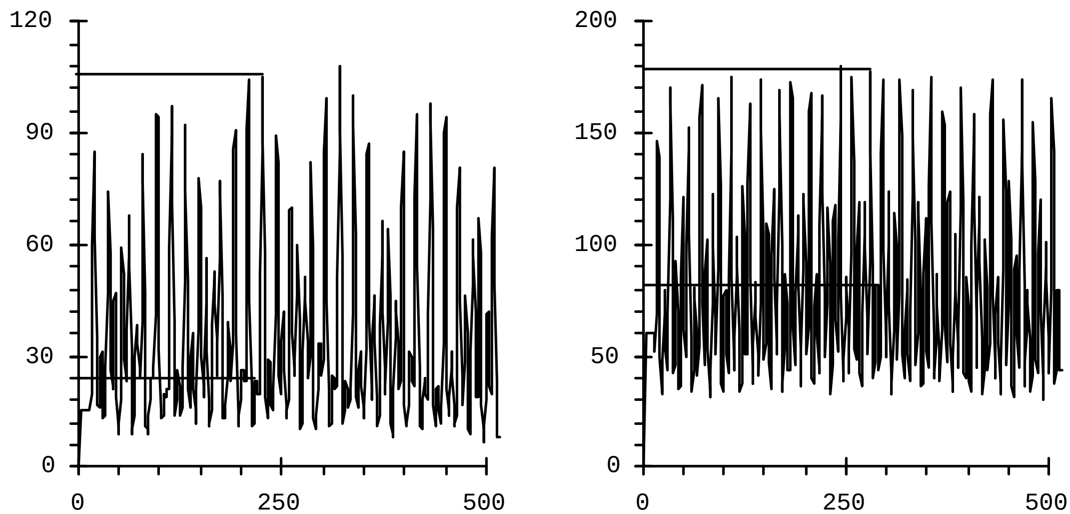
Procedure Measure phosphor pitch in vertical and horizontal dimension at screen center. For aperture grille screens, vertical pitch will be 0. Define pixel size by 1/pixel density.

Data: Define value of phosphor: pixel spacing. Value <1 passes, but <0.6 preferred.

Table II.14-1. Phosphor-to-Pixel-Spacing Ratios

	Monoscopic Mode
Addressability	1600 x 1200
Phosphor Pitch, horizontal	0.25 mm
Pixel Spacing, horizontal	9.52 mils (0.2418 mm)
Phosphor-to-Pixel-Spacing	1.03

Discussion: Moiré occurs when the phosphor pitch is too large in comparison to the pixel size. Studies have shown that a phosphor pitch of about 0.6 pixels or less is required for adequate visibility of image information without interference from the phosphor structure.



Monitor A
0.28mm dot pitch

Monitor B
0.26mm dot pitch

Figure II.14-1. *Contrast modulation for sample luminance profiles (1pixel at level 50, 1 pixel at level 0) for monitors exhibiting moiré due to aliasing.*

In Figure II.14-1, Monitor A phosphor pitch is 0.90 pixels as compared with 0.84 pixels in Monitor B. Moiré is more visible in Monitor A, appearing as long stripes where contrast modulation has been degraded. In Monitor B, moiré is less visible, appearing as "fish-scales" where contrast modulation has been reduced. Even though the Monitor A exhibits a greater loss of contrast modulation from the presence of moiré on 1-on/1-off vertical grille patterns, there is little or no visual impact when aerial photographic images are displayed. NIDL experts in human vision and psychophysics were unable to discern presence of moiré on either monitor when grayscale imagery was displayed.

II.15. Straightness

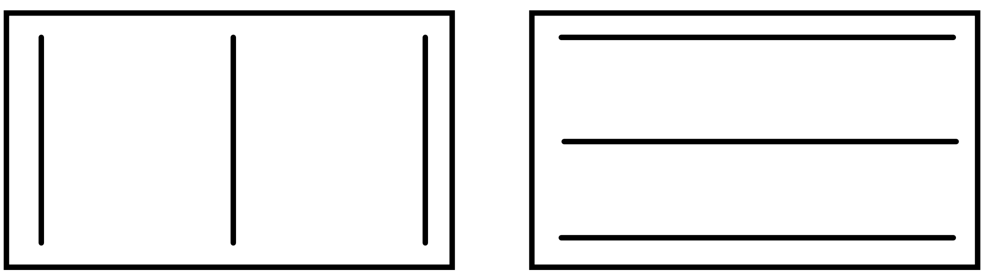
Reference: Monochrome CRT Monitor Performance, Draft Version 2.0, Section 6.1 Waviness, page 67.

Waviness, a measure of straightness, did not exceed 0.21% of the image width or height and passes the IEC specification.

Objective: Measure beam position on the CRT display to quantify effects of waviness which causes nonlinearities within small areas of the display distorting nominally straight features in images, characters, and symbols.

Equipment:
- Video generator
- Spatially calibrated CCD or photodiode array optic module
- Calibrated X-Y translation stage

Test Pattern: Use the three-line grille patterns in Figure II.15-1 for vertical and horizontal lines each 1-pixel wide. Lines in test pattern are displayed at 100% L_{max} must be positioned along the top, bottom, and side edges of the addressable screen, as well as along both the vertical and horizontal centerlines (major and minor axes).



1-pixel-wide lines displayed at 100% L_{max}

Figure II.15-1 Three-line grille test patterns.

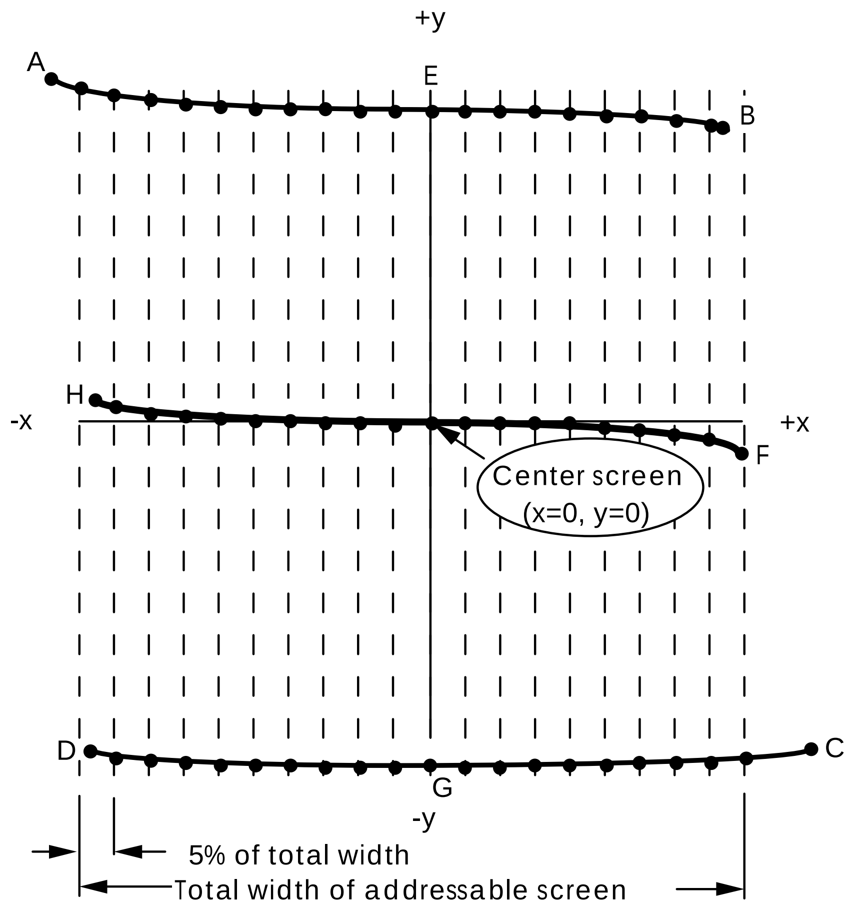


Figure II.15-2 Measurement locations for waviness along horizontal lines. Points A, B, C, D are extreme corner points of addressable screen. Points E, F, G, H are the endpoints of the axes.

Procedure: Use diode optic module to locate center of line profiles in conjunction with calibrated X-Y translation to measure screen x,y coordinates along the length of a nominally straight line. Measure x,y coordinates at 5% addressable screen intervals along the line. Position vertical lines in video to land at each of three (3) horizontal screen locations for determining waviness in the horizontal direction. Similarly, position horizontal lines in video to land at each of three (3) vertical screen locations for determining waviness in the vertical direction.

Data: Tabulate x,y positions at 5% addressable screen increments along nominally straight lines at top and bottom, major and minor axes, and left and right sides of the screen as shown in Table II.15-I. Figure II.15-3 shows the results in graphical form.

Table II.15-1. Straightness

Tabulated x,y positions at 5% addressable screen increments along nominally straight lines.

Top		Bottom		Major		Minor		Left Side		Right Side	
x	y	x	y	x	y	x	y	x	y	x	y
-7610	5755	-7641	-5720	-7629	-8	17	5745	-7610	5755	7595	5718
-7200	5755	-7200	-5720	-7200	-7	12	5200	-7614	5200	7599	5200
-6400	5756	-6400	-5718	-6400	-4	8	4600	-7616	4600	7598	4600
-5600	5755	-5600	-5714	-5600	-1	6	4000	-7618	4000	7600	4000
-4800	5754	-4800	-5710	-4800	1	3	3400	-7618	3400	7603	3400
-4000	5753	-4000	-5708	-4000	1	1	2800	-7619	2800	7602	2800
-3200	5752	-3200	-5708	-3200	2	0	2200	-7621	2200	7601	2200
-2400	5751	-2400	-5710	-2400	2	-1	1600	-7624	1600	7600	1600
-1600	5749	-1600	-5712	-1600	1	-1	1000	-7626	1000	7601	1000
-800	5747	-800	-5715	-800	0	-1	400	-7629	400	7603	400
0	5745	0	-5719	0	0	-1	-200	-7631	-200	7606	-200
800	5743	800	-5723	800	-1	-1	-800	-7633	-800	7609	-800
1600	5742	1600	-5726	1600	-3	-1	-1400	-7636	-1400	7613	-1400
2400	5740	2400	-5729	2400	-4	0	-2000	-7639	-2000	7618	-2000
3200	5737	3200	-5732	3200	-5	1	-2600	-7642	-2600	7622	-2600
4000	5734	4000	-5734	4000	-7	3	-3200	-7643	-3200	7623	-3200
4800	5733	4800	-5737	4800	-9	6	-3800	-7643	-3800	7622	-3800
5600	5731	5600	-5739	5600	-12	10	-4400	-7641	-4400	7620	-4400
6400	5728	6400	-5738	6400	-15	15	-5000	-7639	-5000	7620	-5000
7200	5722	7200	-5735	7200	-20	23	-5600	-7639	-5600	7620	-5600
7595	5718	7622	-5733	7605	-23	26	-5719	-7641	-5720	7622	-5733

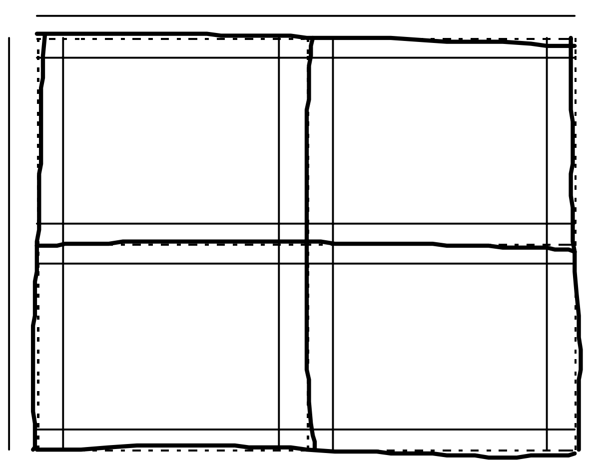


Figure II.15-3 Waviness in 1600 x 1200 mode. Departures from straight lines are exaggerated on a 10X scale. Error bars are +/- 0.5% of total screen size.

II.16. Refresh Rate

Reference: Request for Evaluation Monitors, NIDL Pub. 0201099-091, Section 5.16, p 9.

Vertical refresh rate for 1600 x 1200 format was set to 75 Hz. Vertical refresh rate for the 1024 x 1024 was set to 120 Hz. Vertical refresh rate for 1280 x 1024 stereo format was limited to 118 Hz.

Objective: Define vertical and horizontal refresh rates.

Equipment: Programmable video signal generator.

Procedure: The refresh rates were programmed into the Quantum Data 8701 test pattern generator for 72 Hz minimum for monoscopic mode and 120 Hz minimum for stereoscopic mode, where possible.

Data: Report refresh rates in Hz.

Table II.16-1 Refresh Rates as Tested

	Monoscopic Mode	**Stereoscopic Modes**	
Addressability	1600 x 1200	1024 x 1024	1280 x 1024
Vertical Scan	75 Hz	120 Hz	118 Hz
Horizontal Scan	93.746 kHz	129.417 kHz	126.26 kHz

II.17. Extinction Ratio

Reference: Request for Evaluation Monitors, NIDL Pub. 0201099-091, Section 5.17, p10.

Stereo extinction ratio using the StereoGraphics ZScreen and passive polarized glasses averaged 11:1 (11.2 left, 11.2 right) at screen center. Luminance of white varied by up to 10.5 % across the screen. Chromaticity variations of white were less than 0.006 delta u'v' units. Lmax was 5.1 fL and Lmin was 0.051 fL through the ZScreen and passive glasses. Both values fail to meet the IEC requirements.

Stereo extinction ratio using StereoGraphics LC shutter glasses averaged 18 to 1 (18.4 left, 18.0 right) at screen center, when tested in 1024 x 1024 x 120 Hz (60 Hz per eye) mode. Lmax was 6 fL and Lmin was 0.059 fL through the LC glasses.

Objective: Measure stereo extinction ratio.

Equipment: Two "stereo" pairs with full addressability. One pair has left center at command level of 255 (or Cmax) and right center at 0. The other pair has right center at command level of 255 (or Cmax) and left center at 0.

Stereoscopic-mode measurements were made using commercially available StereoGraphics CrystalEyes 3 Stereoscopic Visualization Eyewear and ENT Emitter. Stereoscopic-mode measurements were also made using a commercially-available StereoGraphics ZScreen with passive polarized eyeglasses.

Procedure: Calibrate monitor to 0.1 fL Lmin and at least 30 fL Lmax for monochrome monitors and at least 6 fL Lmax for color monitors (no ambient) at the analyst's eye position, e.g., through the ZScreen and passive glasses. Measure ratio of Lmax to Lmin on both left and right side images through the stereo system.

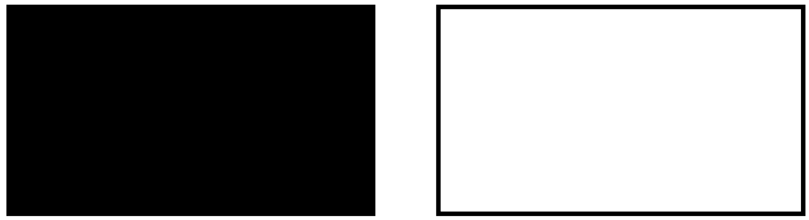
Data: Extinction ratio (left) = L (left,on, white/black)/left,off, black/white)

L(left,on, white/black) ~ trans(left,on)*trans(stereo)*L(max)*Duty(left)
+ trans(left,off)*trans (stereo)*L(min)*Duty (right)
Use left,off/right,on to perform this measurement

Extinction ratio (right) = L (right,on,white/black)/right,off, black/white)

L(right,on, white/black) ~
trans(right,on)*trans(stereo)*L(max)*Duty(right)
+ trans(right,off)*trans (stereo)*L(min)*Duty (left)
Use left,on/right,off to perform this measurement

Stereo extinction ratio is average of left and right ratios defined above.



Left Eye Image Right Eye Image

StereoGraphics ZScreen LC Shutter with Passive Glasses

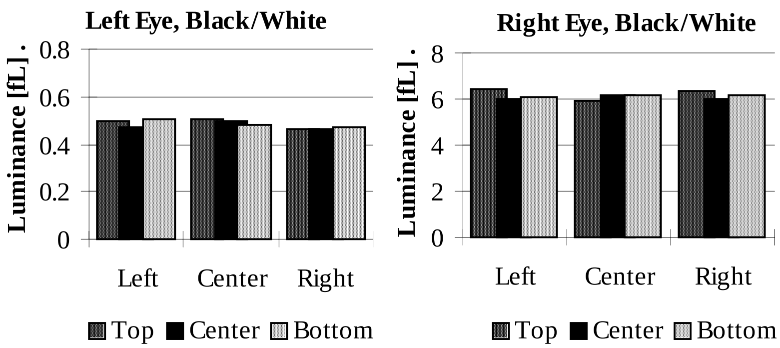
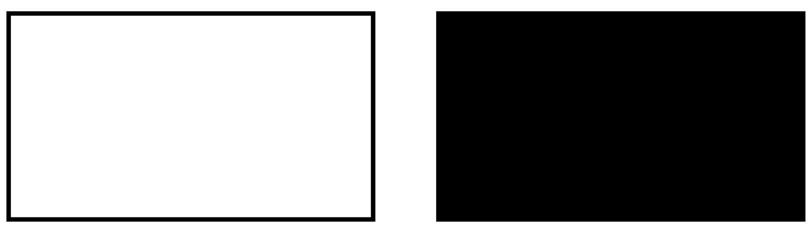


Figure II.17-1. Spatial Uniformity of luminance in stereo mode when displaying black to the left eye while displaying white to the right eye.



Left Eye Image Right Eye Image

StereoGraphics ZScreen LC Shutter with Passive Glasses

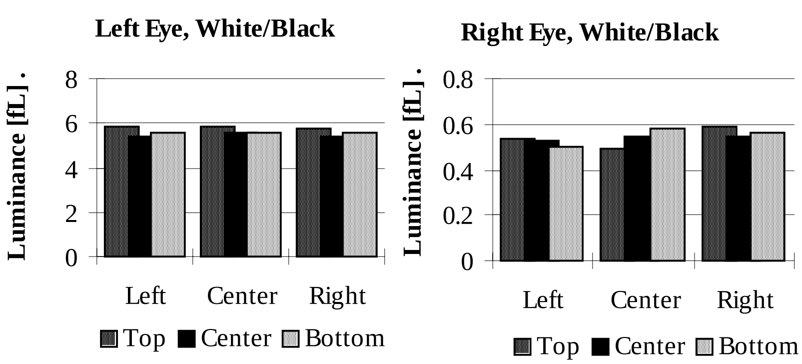


Figure II.17-2. Spatial Uniformity of luminance in stereo mode when displaying white to the left eye while displaying black to the right eye.

StereoGraphics ZScreen LC Shutter with Passive Glasses

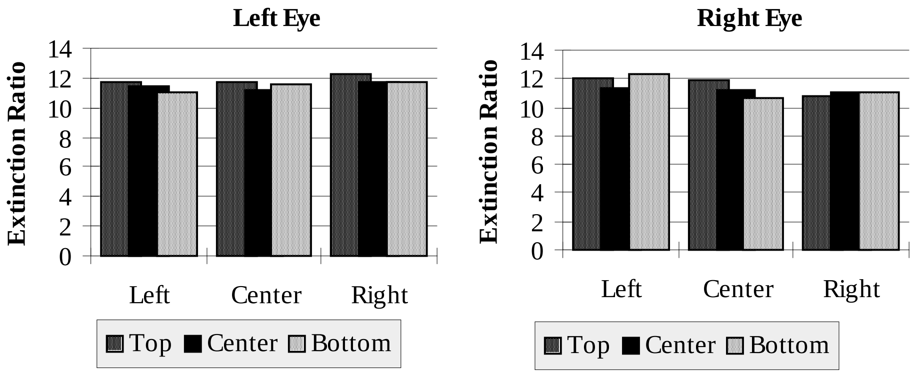
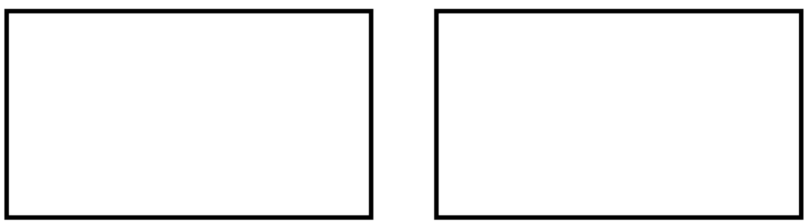


Figure II.17-3. Spatial Uniformity of extinction ratio in stereo mode.



Left Eye Image Right Eye Image

StereoGraphics ZScreen LC Shutter with Passive Glasses

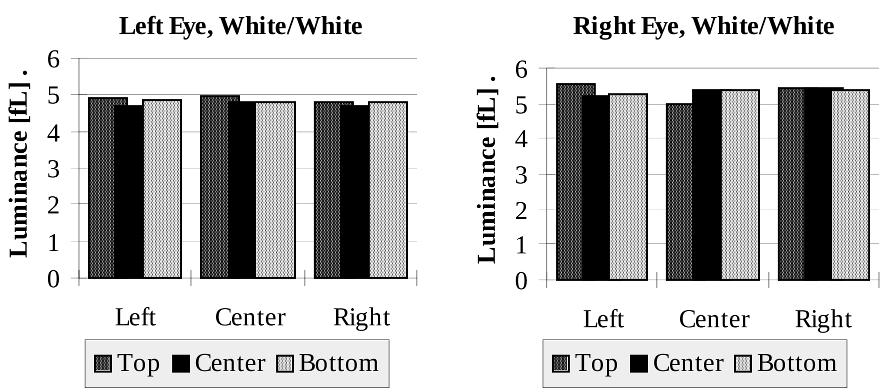


Figure II.17-4. Spatial uniformity of luminance of white in stereo mode.

Left Eye Image Right Eye Image

StereoGraphics ZScreen LC Shutter with Passive Glasses

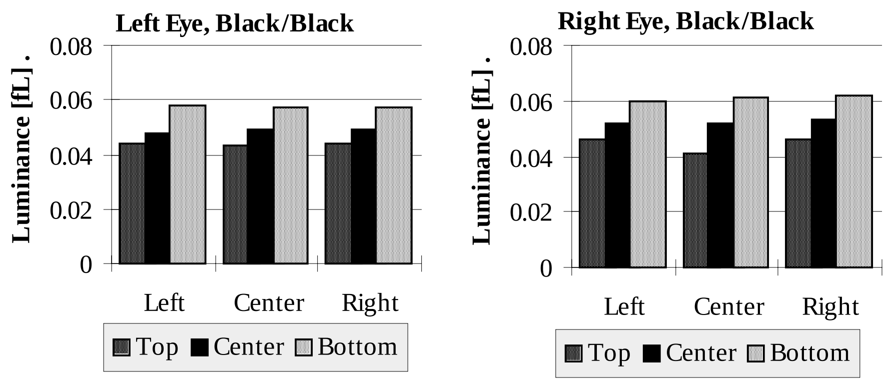
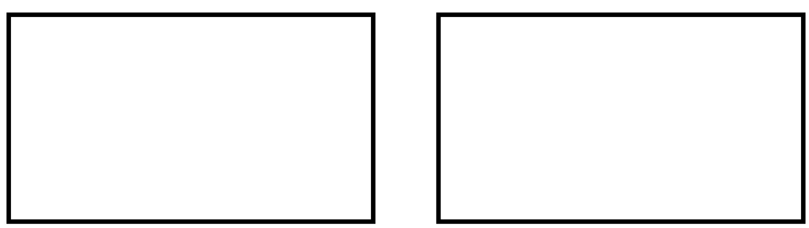


Figure II.17-5. Spatial uniformity of luminance of black in stereo mode.



Left Eye Image Right Eye Image

StereoGraphics ZScreen LC Shutter with Passive Glasses

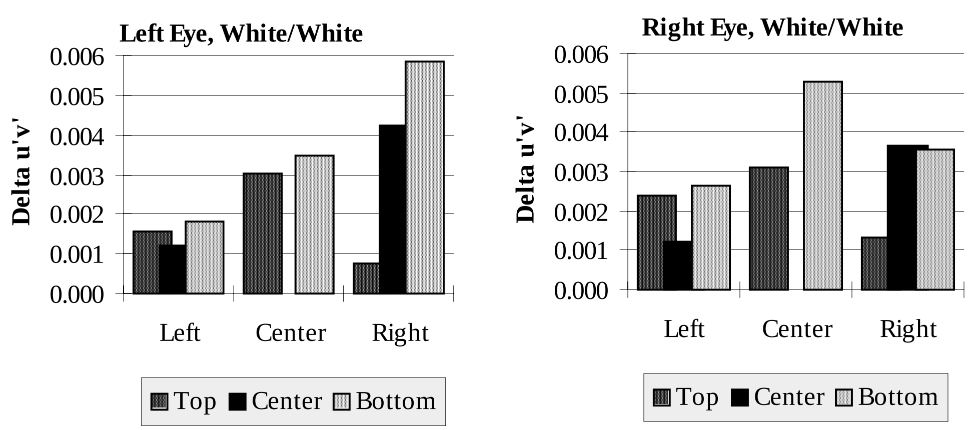


Figure II.17-6. Spatial uniformity of chromaticity of white in stereo mode.

II.18. Linearity

Reference: Monochrome CRT Monitor Performance, Draft Version 2.0, Section 6.2, page 73.

The maximum nonlinearity of the scan was 0.32% of full screen and passes the IEC specification.

Objective: Measure the relation between the actual position of a pixel on the screen and the commanded position to quantify effects of raster nonlinearity. Nonlinearity of scan degrades the preservation of scale in images across the display.

Equipment:
- Video generator
- Spatially calibrated CCD or photodiode array optic module
- Calibrated X-Y translation stage

Test Pattern: Use grille patterns of single-pixel horizontal lines and single-pixel vertical lines displayed at 100% L_{max}. Lines are equally spaced in addressable pixels. Spacing must be constant and equal to approximately 5% screen width and height to the nearest addressable pixel as shown in Figure II.18-1.

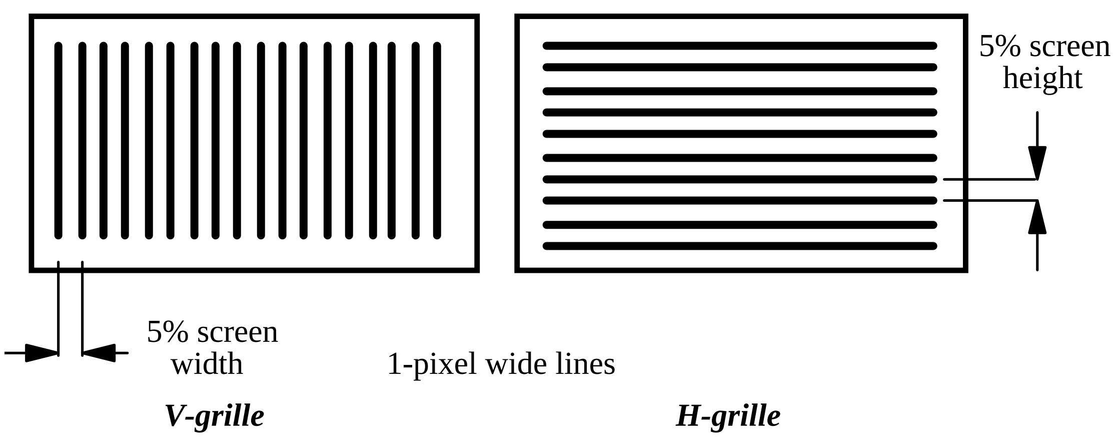


Figure II.18-1. *Grille patterns for measuring linearity*

Procedure: The linearity of the raster scan is determined by measuring the positions of lines on the screen. Vertical lines are measured for the horizontal scan, and horizontal lines for the vertical scan. Lines are commanded to 100% Lmax and are equally spaced in the time domain by pixel indexing on the video test pattern. Use optic module to locate center of line profiles in conjunction with x,y-translation stage to measure screen x,y coordinates of points where video pattern vertical lines intersect horizontal centerline of screen and where horizontal lines intersect vertical centerline of the CRT screen as shown in Figure II.18-2.

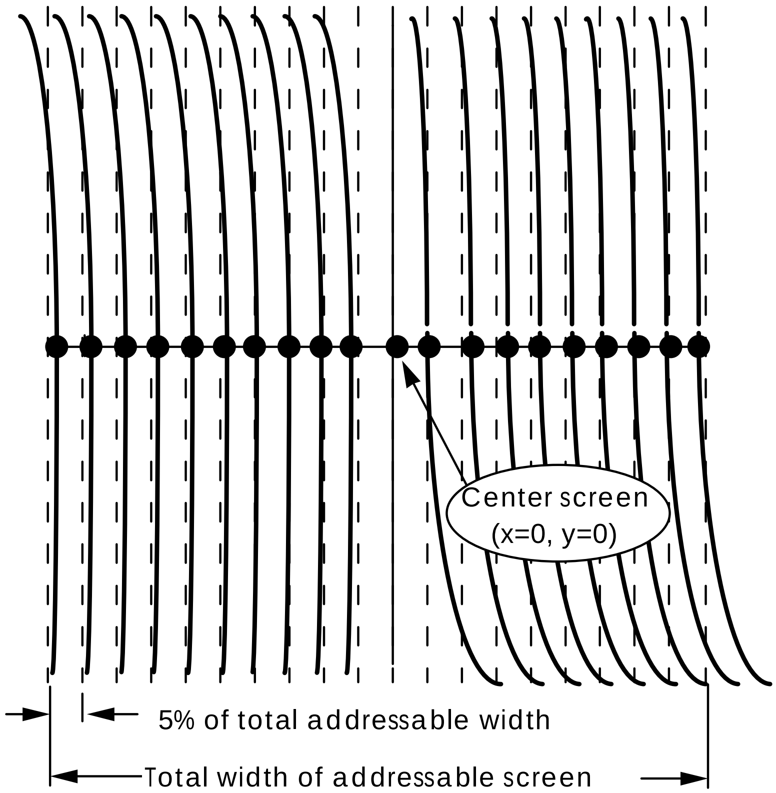


Figure II.18-2. *Measurement locations for horizontal linearity along the major axis of the display. Equal pixel spacings between vertical lines in the grille pattern are indicated by the dotted lines. The number of pixels per space is nominally equivalent to 5% of the addressable screen size.*

Data: Tabulate x, y positions of equally spaced lines (nominally 5% addressable screen apart) along major (horizontal centerline) and minor (vertical centerline) axes of the raster. If both scans were truly linear, the differences in the positions of adjacent lines would be a constant. The departures of these differences from constancy impact the absolute position of each pixel on the screen and are, then, the nonlinearity. The degree of nonlinearity may be different between left and right and between top and bottom. The maximum horizontal and vertical nonlinearities (referred to full screen size) are listed in table II.18-1. The complete measured data are listed in table II.18-2 and shown graphically in Figures II.18-3 and II.18-4.

Table II.18-1. Maximum Horizontal and Vertical Nonlinearities

Format	Left Side	Right Side	Top	Bottom
1600 x 1200	0.18%	-0.32%	0.03%	0.25%

Table II.18-2. Horizontal and Vertical Nonlinearities Data

Vertical Lines x-Position (mils)		Horizontal lines y-Position (mils)	
Left Side	Right Side	Top	Bottom
-7637	7616	5748	-5721
-6857	6839	5179	-5159
-6085	6067	4604	-4592
-5321	5299	4029	-4022
-4562	4541	3451	-3451
-3807	3793	2873	-2877
-3053	3042	2299	-2302
-2291	2288	1725	-1728
-1526	1527	1150	-1151
-760	768	575	-575
0	0	0	0

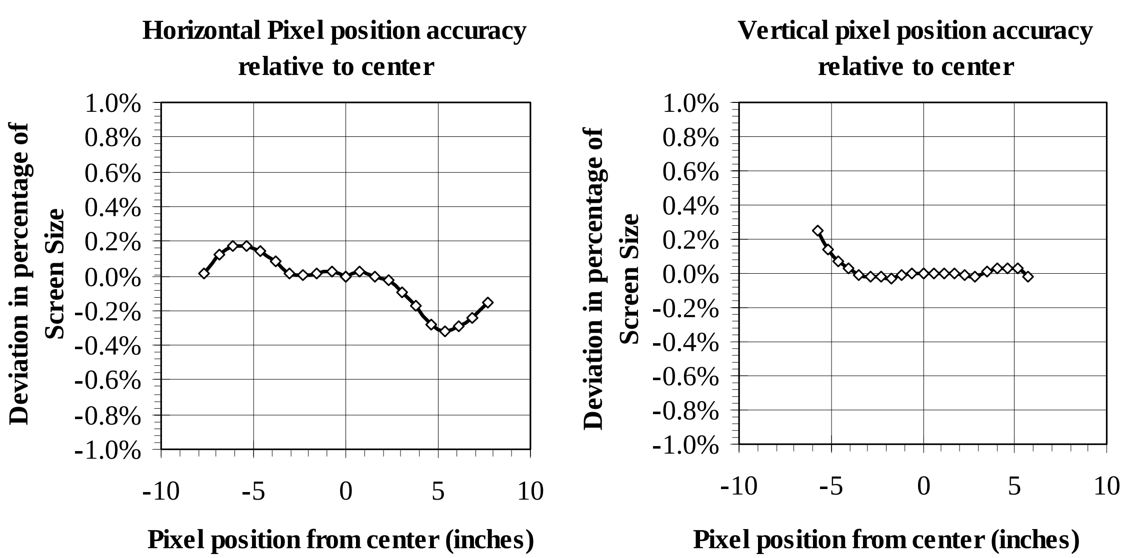


Figure II.18-3. Horizontal and Vertical Linearity Characteristics.

II.19. Jitter/Swim/Drift

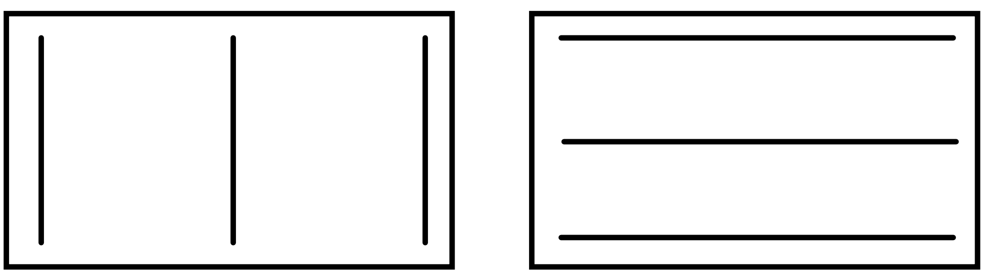
Reference: Monochrome CRT Monitor Performance, Draft Version 2.0 Section 6.4, p80.

Maximum jitter and swim/drift were 3.85 mils and 4.34 mils, respectively, and pass the IEC specification.

Objective: Measure amplitude and frequency of variations in beam spot position of the CRT display. Quantify the effects of perceptible time varying raster distortions: jitter, swim, and drift. The perceptibility of changes in the position of an image depends upon the amplitude and frequency of the motions, which can be caused by imprecise control electronics or external magnetic fields.

Equipment:
- Video generator
- Spatially calibrated CCD or photodiode array optic module
- Calibrated X-Y translation stage

Test Pattern: Use the three-line grille patterns in Figure II.19-1 for vertical and horizontal lines each 1-pixel wide. Lines in test pattern must be positioned along the top, bottom, and side edges of the addressable screen, as well as along both the vertical and horizontal centerlines (major and minor axes).



V-grille for measuring horizontal motion H-grille for measuring vertical motion

1-pixel wide lines

Three-line grille test patterns.
Figure II.19-1.

Procedure: With the monitor set up for intended scanning rates, measure vertical and horizontal line jitter (0.01 to 2 seconds), swim (2 to 60 seconds) and drift (over 60 seconds) over a 2.5 minute duration as displayed using grille video test patterns. Generate a histogram of raster variance with time. The measurement interval must be equal to a single field period.

Optionally, for multi-sync monitors measure jitter over the specified range of scanning rates. Some monitors running vertical scan rates other than AC line frequency may exhibit increased jitter.

Measure and report instrumentation motion by viewing Ronchi ruling or illuminated razor edge mounted to the top of the display. It may be necessary to mount both the optics and the monitor on a vibration damped surface to reduce vibrations.

Data: Tabulate motion as a function of time in x-direction at top-left corner screen location. Repeat for variance in y-direction. Tabulate maximum motions (in mils) with display input count level corresponding to L_{max} for jitter (0.01 to 2 seconds), swim (2 to 60 seconds) and drift (over 60 seconds) over a 2.5 minute duration. The data are presented in Table II.19-1. Both the monitor and the Microvision equipment sit on a vibration-damped aluminum-slab measurement bench. The motion of the test bench was a factor of 10 times smaller than the CRT raster motion.

Table II.19-1. Jitter/Swim/Drift

Time scales: Jitter 2 sec., Swim 10 sec., and Drift 60 sec.
Moiré Compensation OFF

1600 x 1200 x 75 Hz

	Max Motions	H-lines	V-lines	
10D corner				
	Jitter	1.57	4.05	
	Swim	1.72	4.28	
	Drift	1.76	4.57	
Black Tape				
	Jitter	0.233	0.197	
	Swim	0.249	0.197	
	Drift	0.149	0.234	
Less Tape Motion				maximums
	Jitter	1.34	3.85	3.85
	Swim	1.47	4.08	4.08
	Drift	1.61	4.34	4.34

II.20. Warm-up Period

Reference: Request for Evaluation Monitors, NIDL Pub. 0201099-091, Section 5.20, p. 10.

A 48 minute warm-up period was necessary for luminance stability of Lmin to within 10% of its final value, thereby meeting the IEC specification.

Objective: Define warm-up period

Equipment: Photometer, test target (full screen 0 count)

Procedure: Turn monitor off for three-hour period. Turn monitor on and measure center of screen luminance (Lmin as defined in Dynamic range measurement) at 1-minute intervals for first five minutes and five minute intervals thereafter. Discontinue when three successive measurements are ± 10% of Lmin.

Data: Pass if Lmin within ± 50% in 30 minutes and ±10% in 60 minutes.

The luminance of the screen (commanded to the minimum input level, 0 for Lmin) was monitored for 120 minutes after a cold start. Measurements were taken every minute. Figure II.20-1 shows the data for 1600 x 1200 format in graphical form. The luminance remains very stable after 60 minutes.

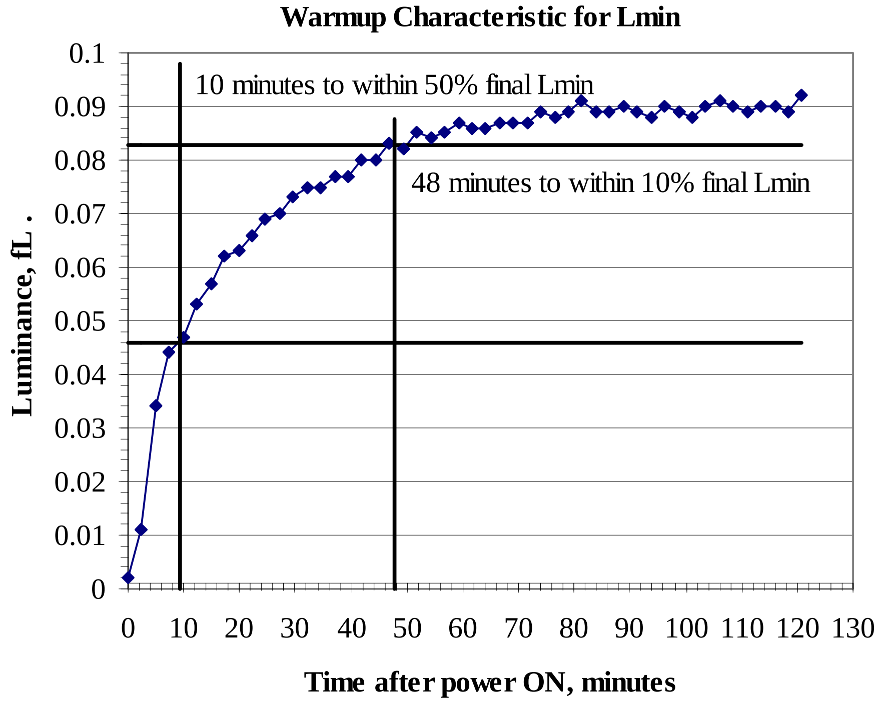


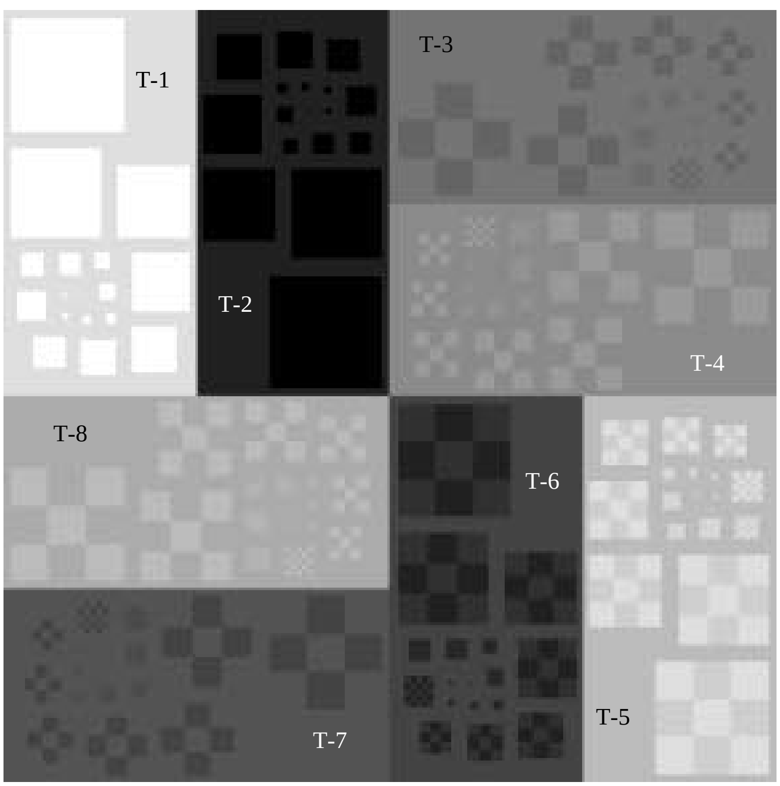
Figure II.20-1. Luminance (fL) as a function of time (in minutes) from a cold start with an input count of 0.

II. 21. Briggs Scores

Reference: SofTrak User's Guidelines and Reference Manual version 3.0, NIDL, Sept. 1994, p 3.

Briggs scores for the BTP #4 Delta-1, Delta-3, Delta-7 and Delta-15 contrast ratio targets sets averaged 8, 40, 53 and 57, respectively, for the Cornerstone p1750 monitor. The p1750 scores were comparable to the Cornerstone P1700 monitor and were somewhat lower than for the Sony GDM-520 monitor. The reported values are base scores.

The Briggs series of test targets illustrated in Figures II.21-1 were developed to visually evaluate the image quality of grayscale monitors. Three NIDL observers selected the maximum scores for each target set shown in Figure II.21-2 displayed on the Cornerstone p1750 22-inch flat face Trinitron-type CRT monitor driven using a Quantum Data 8701 400 MHz programmable test pattern generator. For comparison, Briggs scores are also shown for the Cornerstone P1700 21-inch curved face shadowmask CRT monitor and for the Sony GDM-F520 flat face CRT monitor. Magnifying devices were used when deemed by the observer to be advantageous in achieving higher scores. The reported values plotted in Figure II.21-3 and listed in Table II.21-1 are base scores.



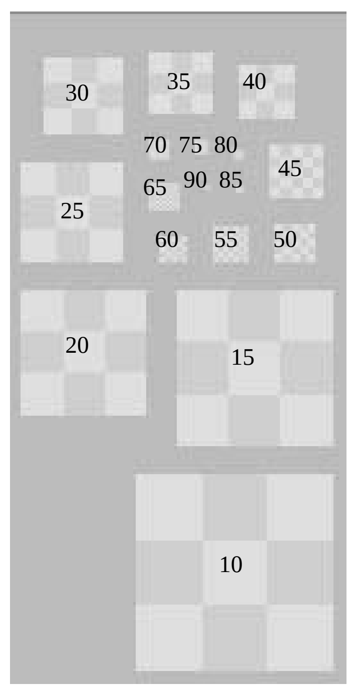


Figure II.21-1. Briggs BPT#4 Test Patterns comprised of 8 targets labeled T-1 through T-8. A series of 17 checkerboards are contained within each of the 8 targets. Each checkerboard is assigned a score value ranging from 10 to 90. Higher scores are assigned to smaller checkerboards.

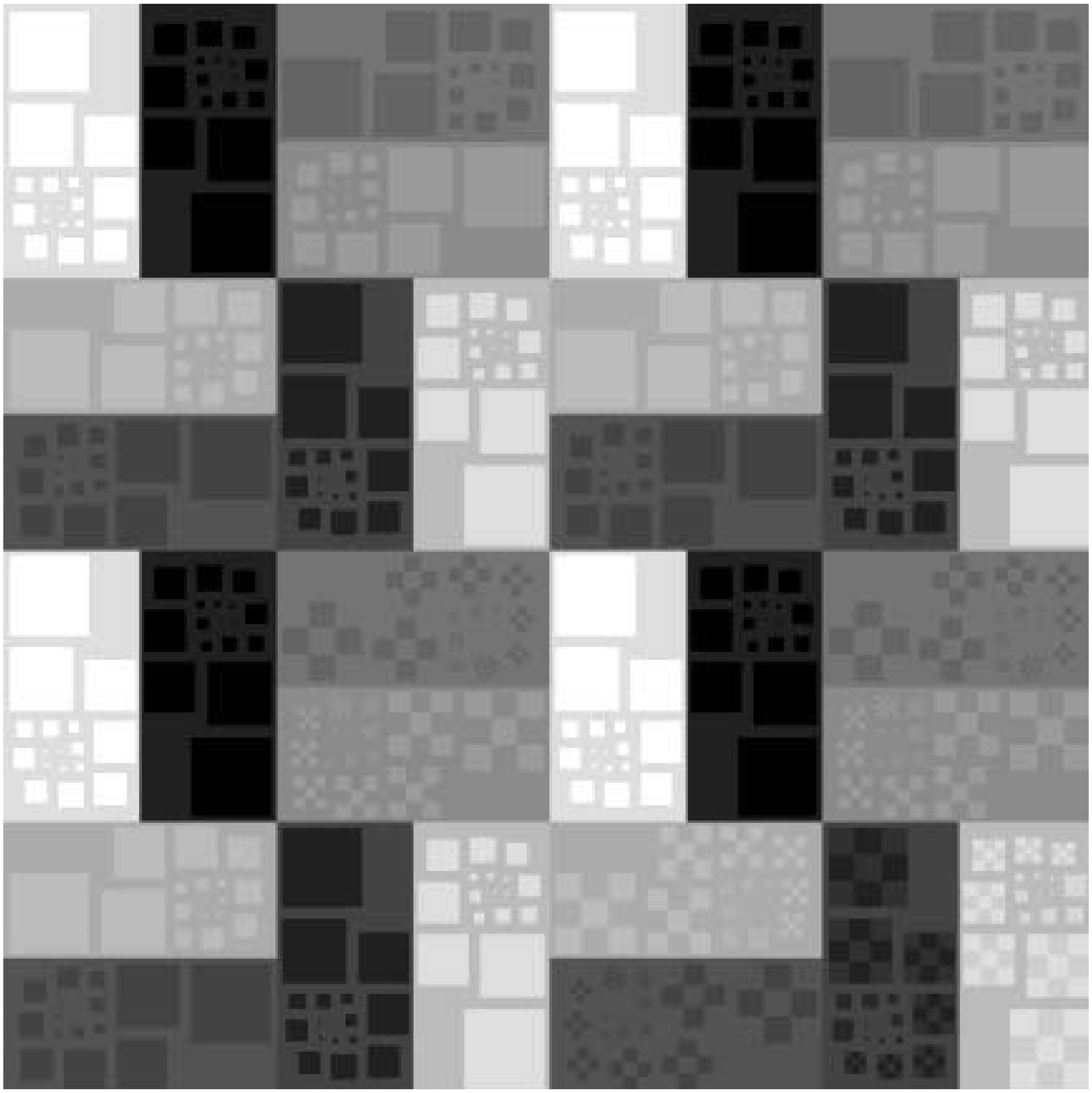


Figure II.21-2. 1024 x 1024 mosaic comprised of four 512 x 512 Briggs BPT#4 Test Patterns. The upper left quadrant contains the set of 8 Briggs targets with command contrast of delta 1. The upper right quadrant contains command contrast of delta 3. Delta 7 targets are in the lower left quadrant and delta 15 targets are in the lower right.

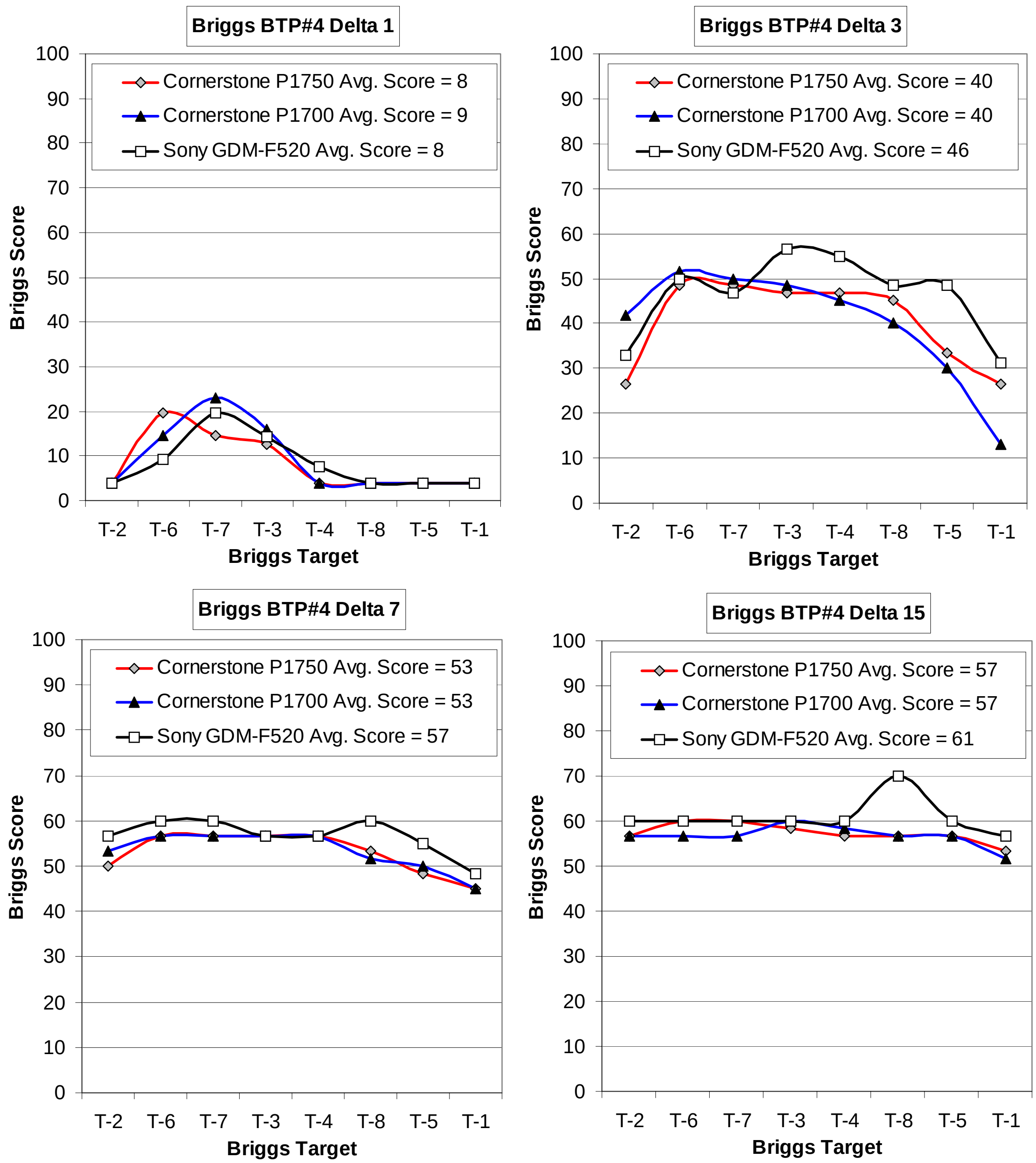


Figure II.21-3. Briggs Scores averaged for three NIDL observers for Delta-1, Delta-3, Delta-7 and Delta-15 contrast ratios on BPT#4 Test Patterns for the Cornerstone p1750 22-inch flat face Trinitron-type CRT monitor compared to the Cornerstone P1700 21-inch curved face shadowmask CRT monitor and compared to the Sony GDM-F520 flat face CRT monitor.

Table II.21-1. Briggs Scores

Briggs Scores for 1600 x 1200 Monoscopic Mode

	Cornerstone P1750 Avg. Score = 8				**Sony GDM-F520 Avg. Score = 8**				**Cornerstone P1700 Avg. Score = 9**			
	Observer				**Observer**				**Observer**			
Delta-1	**1**	**2**	**3**	**Average**	**1**	**2**	**3**	**Average**	**1**	**2**	**3**	**Average**
T-2 Dark	4	4	4	4	4	4	4	4	4	4	4	4
T-6	15	4	40	20	4	20	4	9	4	20	20	15
T-7	4	15	25	15	4	25	30	20	4	20	45	23
T-3	4	30	4	13	4	35	4	14	4	40	4	16
T-4	4	4	4	4	4	15	4	8	4	4	4	4
T-8	4	4	4	4	4	4	4	4	4	4	4	4
T-5	4	4	4	4	4	4	4	4	4	4	4	4
T-1 Bright	4	4	4	4	4	4	4	4	4	4	4	4
			AVERAGE	8			AVERAGE	8			AVERAGE	9

	Cornerstone P1750 Avg. Score = 40				**Sony GDM-F520 Avg. Score = 46**				**Cornerstone P1700 Avg. Score = 40**			
	Observer				**Observer**				**Observer**			
Delta-3	**1**	**2**	**3**	**Average**	**1**	**2**	**3**	**Average**	**1**	**2**	**3**	**Average**
T-2 Dark	4	45	30	26	4	50	45	33	30	45	50	42
T-6	45	50	50	48	40	50	60	50	45	50	60	52
T-7	45	50	50	48	40	50	50	47	50	50	50	50
T-3	40	50	50	47	50	60	60	57	45	50	50	48
T-4	40	50	50	47	50	55	60	55	40	45	50	45
T-8	40	45	50	45	40	50	55	48	30	45	45	40
T-5	15	40	45	33	35	50	60	48	5	45	40	30
T-1 Bright	4	45	30	26	4	45	45	31	5	30	4	13
			AVERAGE	40			AVERAGE	46			AVERAGE	40

	Cornerstone P1750 Avg. Score = 53				**Sony GDM-F520 Avg. Score = 57**				**Cornerstone P1700 Avg. Score = 53**			
	Observer				**Observer**				**Observer**			
Delta-7	**1**	**2**	**3**	**Average**	**1**	**2**	**3**	**Average**	**1**	**2**	**3**	**Average**
T-2 Dark	50	50	50	50	50	60	60	57	50	50	60	53
T-6	50	60	60	57	60	60	60	60	50	60	60	57
T-7	50	60	60	57	60	60	60	60	50	60	60	57
T-3	50	60	60	57	50	60	60	57	50	60	60	57
T-4	50	60	60	57	50	60	60	57	50	60	60	57
T-8	50	50	60	53	60	60	60	60	50	50	55	52
T-5	45	50	50	48	50	55	60	55	50	50	50	50
T-1 Bright	40	45	50	45	40	50	55	48	45	45	45	45
			AVERAGE	53			AVERAGE	57			AVERAGE	53

	Cornerstone P1750 Avg. Score = 57				**Sony GDM-F520 Avg. Score = 61**				**Cornerstone P1700 Avg. Score = 57**			
	Observer				**Observer**				**Observer**			
Delta-15	**1**	**2**	**3**	**Average**	**1**	**2**	**3**	**Average**	**1**	**2**	**3**	**Average**
T-2 Dark	50	60	60	57	60	60	60	60	50	60	60	57
T-6	60	60	60	60	60	60	60	60	50	60	60	57
T-7	60	60	60	60	60	60	60	60	50	60	60	57
T-3	55	60	60	58	60	60	60	60	60	60	60	60
T-4	50	60	60	57	60	60	60	60	55	60	60	58
T-8	50	60	60	57	60	60	90	70	50	60	60	57
T-5	50	60	60	57	60	60	60	60	50	60	60	57
T-1 Bright	50	50	60	53	50	60	60	57	50	55	50	52
			AVERAGE	57			AVERAGE	61			AVERAGE	57

II. 22. Output Luminance with Color Temperature Setting

The luminance of a white full screen, Lmax, is the same for both 9300 K and 6500 K preset color temperatures. The measured CCTs are 8811 K and 6565 K, respectively.

The Cornerstone p1750 color monitor has preset color temperatures: 5000, 6500, 9300K and a setting for sRGB. NIDL made measurements of the output luminance for 6500 K and 9300 K preset color temperatures. These results are shown in Table II.22-1. The output luminance is essentially the same at 9300K compared to 6500K. Some within the IEC community have advocated 6500K as being closer to natural light, and therefore appropriate for viewing color imagery taken in daylight. However, a CCT of 9300K more closely matches that of monochrome monitors used for exploitation and is the default for many color monitors.

Table II.22-1. Measured Luminance and Color Temperature for Preset Modes

CCT Preset	6500 K	9300 K
CCT measured	6565 K	8811 K
CIE x	0.3106	0.2838
CIE y	0.3353	0.3078
Lmin, fL	0.104	0.103
Lmax, fL	34.15	34.00

II. 23. Luminance Loading

Reference: VESA FPDM Version 2.0, Section 304-8, page 95.

Reducing the size of a full screen to a 2-inch square target increases the white luminance of the Cornerstone p1750 monitor by 30%. This strong effect was not observed for the Cornerstone P1700 or the Sony F520 monitors.

Table II.23-1. Luminance Loading Measurements

Cornerstone p1750			Cornerstone P1700			Sony F520		
2-inch target	Full screen	Change	2-inch target	Full screen	Change	2-inch target	Full screen	Change
						37.7	37.9	-0.5%
						36.0	36.1	-0.3%
43.4	33.4	30%				34.9	34.9	0.0%
33.7	31.4	7.3%	33.8	31.5	7.3%	32.5	32.5	0.0%
31.8	30.0	6.0%	32.4	30.5	6.2%	29.7	29.6	0.3%
29.0	27.6	5.1%	29.5	27.4	7.7%	27.5	27.4	0.4%
26.6	25.2	5.6%	26.6	25.2	5.6%	25.0	25.0	0.0%
23.8	22.7	4.8%	24.1	22.7	6.2%	22.2	22.2	0.0%
21.5	20.4	5.4%	21.5	20.3	5.9%	19.9	20.0	-0.5%

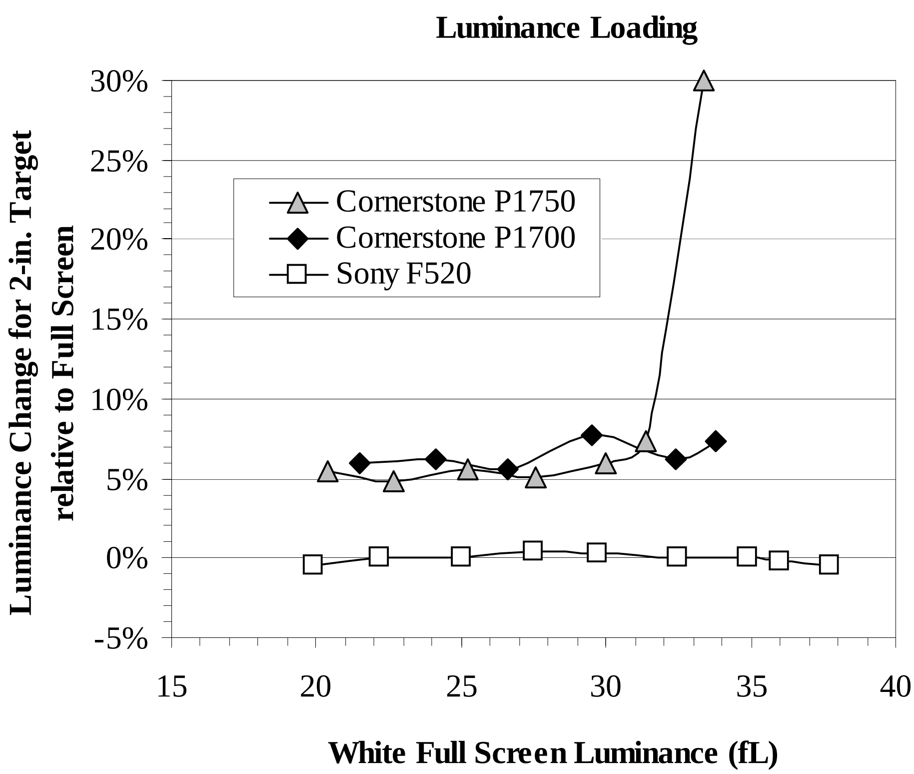


Figure II.23-1. Luminance loading characteristics of the Cornerstone p1750 and P1700 monitors compared to the Sony GDM-F520 monitor.